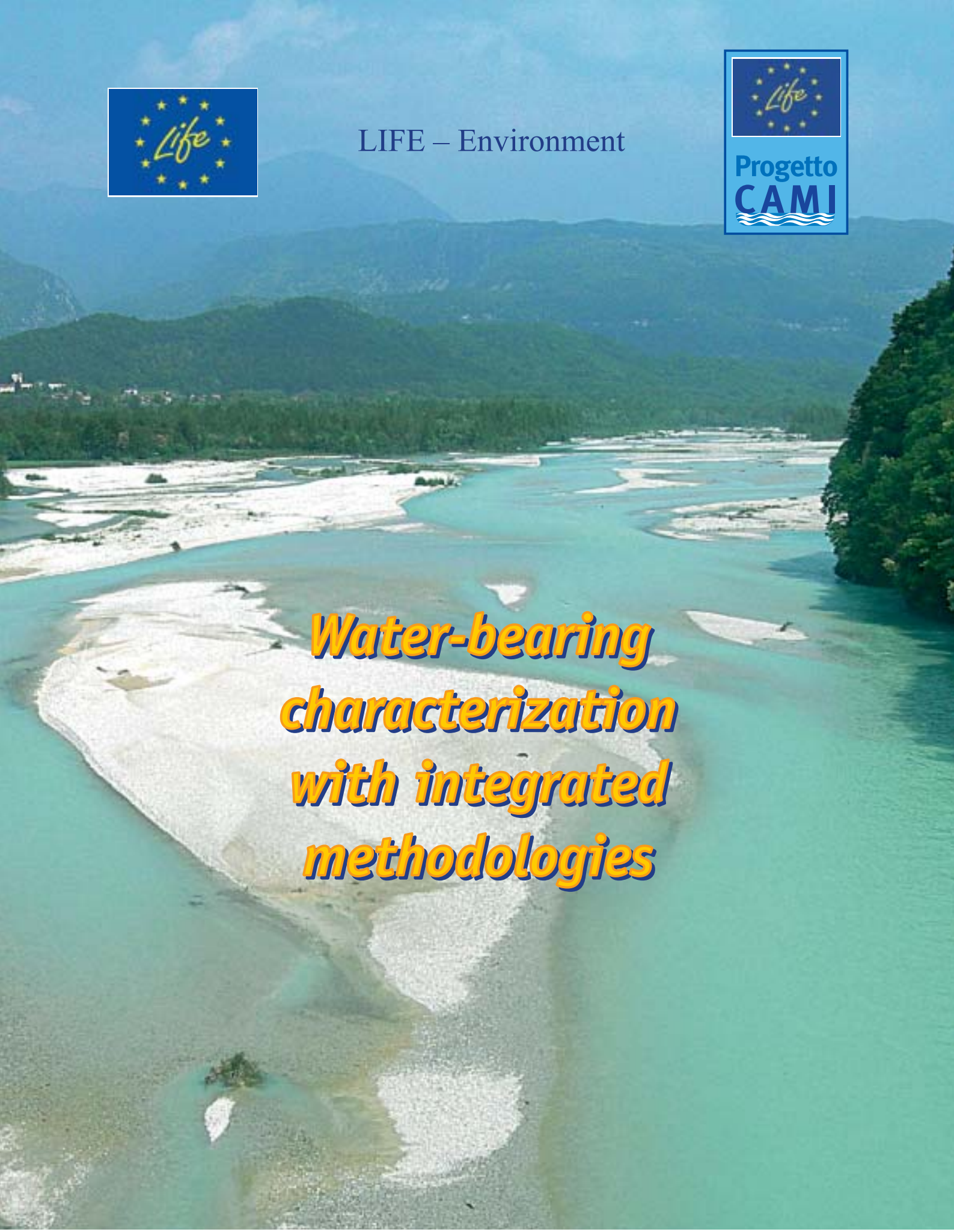
LIFE – Environment

Progetto CAMI



Water-bearing characterization with integrated methodologies

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS

Università degli Studi di Trieste Dipartimento di Scienze Geologiche Ambientali e Marine

Università degli Studi di Ferrara – Dipartimento di Scienze della Terra

EUREKOS S.r.l.

ARPA - Agenzia Regionale per la Protezione dell'Ambiente del Friuli Venezia Giulia – Dipartimento Provinciale di Pordenone

ABL - Acque del Basso Livenza S.p.A.

TNO - Netherlands Organisation for Applied Scientific Research

Water-bearing characterization with integrated methodologies

Water and Environment

Water is a natural resource and is the base of life in our planet.
In the last years the awareness that water is a limited resource has became a reality also in area where it is abundant.
The indiscriminate use of water, the poor protection of the groundwater and of the recharge areas represent a important menace for its availability and use for the next generations.

European Union has always demonstrated a great sensibility for environmental topics and in particular for those related to water cycle.
These ones are well represented in the goals of the LIFE programme as expressed in the promotion of the concept of sustainable exploitation of surface and underground water.
In this framework Institutions, research Centres public and private operators and all the actors involved in the environmental sectors inside the EU and abroad are requested to have a strong professional role .
On this base the realisation of one the most important directive for the protection of the water resource has been proposed and obtained.

Tagliamento river – Ragogna (UD).

The CAMI Project

The CAMI Project (Water-bearing characterization with integrated methodologies) has been co-financed by the EU in the frame of the LIFE programme.
It contributes to the enforcement of the EU directive 2000/60/CE and further modifications by developing and testing an integrated method aimed at the definition and characterization of the hydro geological districts, the analysis of the environmental impact of human activities on the water resource and to the evaluation of sustainability.

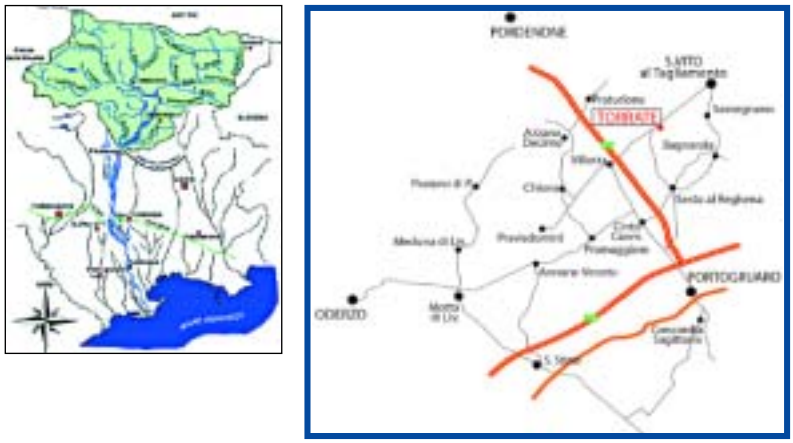
The water directive 2000/60/CE introduce in the EU legislation the innovative concept of the management of water resources based on hydro geological basins instead on administrative limits and districts.

The CAMI Project permitted to develop an integrated approach based on geophysical, geochemical and monitoring activities covering a whole hydro geological basin and applied in the test area of Torrate di Chions (PN-Italy).

Piezometric tower – ABL (Torrate di Chions).

Hydrogeological distric and test area

One of the main components of the CAMI project is the experimental activity.
It is based on a series of investigation campaigns in the territory of the pedmontain area belonging to the Veneto Region and the Friuli Venetia Giulia Region between the Meduna-cellina and Tagliamento rivers.
The area is characterised by high permeability alluvial fans hosting one of the most important aquifers of the two regions.
The intensive agriculture, the industrial settlements and the high urbanisation determine the high vulnerability of this aquifer.



Hydrographic basin of Tagliamento river. Location of the study area.

Actions

The filed surveys and the geochemical analyses and the geophysical investigations permitted to:

1) determine the feeding reservoirs and their interactions by the study of isotopic analysis of O18 and Tritium Activity on samples collected from underground and surface waters, rainfall and snow;
2) Precisely understand the subsoil by the 3D reconstruction of the system of exploited aquifers and the characterization of the typical petrophysical, hydraulic and hydrochemical parameters;
3) To determine the hydrodynamic characteristics of the aquifer during exploitation.

Area test.

Seismic survey in the study area.

Project set-up

The project is organised in a series of tasks and actions developed acconrding to the following scheme:

1) Gathering and organisation of available data;
2) Stratigraphycal analysis, construction of preliminary geological model and design of geophysical investigations;
3) Realization of the geochemical and isotopic data collection;
4) Realization of geophysical surveys;
5) Interpretaion of geophysical data and integration of the hydrogeological model;
6) Hydrogeological interpretation and modelling of the aquifer;
7) Realization of thematical maps, maps of recharge/dispersion areas, vulnerabiliy, etc.;
8) Modelling of aquifer by REGIS software;
9) Construction of a model of the spring barrier system and development of a protocol for the characyterization of hydrogeological basins as (Dir, 2000/60/CE);
10) Dissemination of results by web site(state of advancement of the research, intermediate results, final results) conferences, seminars and multimedia material.

Final goal of the project

The goal of the project is the determination of a investigation and monitoring protocol to guarantee homogenous results in different hydrogeological settings as specially required by the EU directive.

PARTENER TASK OBJECTIVE

Organizational structure: tasks and objectives assigned to the participants of the CAMI project

OGS, as beneficiary of the project, proposed to the six working partners in the technical-scientific sector (two public Corporate body and three public Institutions and a private Structure) a multidisciplinare pilot project for the implementation of the European legislation through the community programs LIFE.

The National Institute of Oceanography and Experimental Geophysics - OGS

- **To coordinate partners activity – Dissemination**
- **Integrated geophysics for modelling the hydrographical district**
- **Geophysical surveying results**

The contribution of geophysics in the projects is related to the characterization of the geology of the test area through the idefinition of the vertical and lateral heterogeneities of the physical properties of the bodies in which the aquifers are confined.
The methodologies used have different degree of penetration and resolution. It have been used the followings geophysical prospecting: Ground Penetrating Radar, Gravimetric, Geoelectric and Reflection Seismic.

University of Studies of Trieste
Department of Geological Environmental and Marine Sciences

- **Aquifer assessment through isotopic geochemistry**

Isotopic characterization of circulating waters (meteoric, surface and ground waters) in the recharge zone of the main site of Torrate can define the recharge areas and supply information about the mutual connections between several waters.
The oxygen isotope composition and the radon content have been determined on monthly samples; bi-monthly samples have been measured for tritium activity.

University of Ferrara
Department of Earth Sciences

- **Qualitative and dynamic characterization of the aquifer based on geophysical and geochemical integrated methodologies**

The University of Ferrara has provided a hydrogeological conceptual model of the aquifer system and has contributed to the set up of a geophysical and geochemical integrated methodology allowing to understand and evaluate the behaviour of the aquifers existing in the investigated area. These goals have been achieved based on pumping tests, installation of a multiparametric probes and the geophysical parametrization of the subsoil with non-invasive methods (magnetotelluric and TDEM methods).

Progetto CAMI

ABL - Acque del Basso Livenza S.p.A.

- **Providing data for the updating of the geohydrological database, assessment of the geohydrological model, improving the knowledgement about the ground water system**

ABL provided a collection of historical data, enclosing stratigraphies and pump test on "Torrate Area", and supplied logistic assistance for geophysical and geochemical tests; moreover, ABL helped to assess and disseminate the final results.

Eurekos S.r.l.

- **Integrated application of high resolution and fast geophysical methods: airborne thermography and GPR on the spring barrier system for the modelling of flow and evaluation of vulnerability**

The main goal of this task is the application of a fast and precise methodology able to define the hydro geological mechanisms responsible for the formation and existence of a spring barrier system. It can be obtained by the application of thermography for the study of the thermal anomalies determined by the rising of spring waters.
This survey has bee supported by a GPR investigation for the mapping of the shallow stratigraphy aimed at the reconstruction and correlation of the levels allowing the water movements.

ARPA - Environmentl Regional Protection Agency of Friuli Venezia Giulia
Local department of Pordenone

- **Acquisition and elaboration of deepwater analytical data**
- **Acquisition and elaboration of meteorological data**
- **Taking of rain and well samples**
- **Spread of the results**

The ARPA Department of Pordenone supplied analitical data about groundwater composition in the Pordenone province preparing a data base with 500 well chemical analysis. The monthly sampling of deep water and rain to perform isotopic analysis by Trieste university aimed to create a correlation model about deep water circulation in the studied area.

Netherlands Organisation for Applied Scientific Research
TNO-NITG

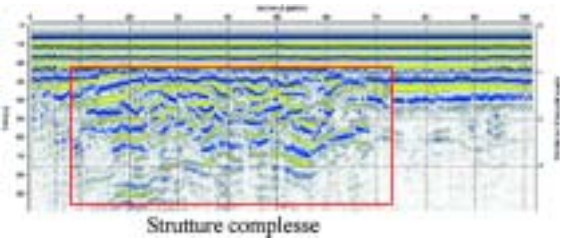
- **Development and implementation of a Regional Geohydrological Information System (REGIS)**
- **Development, calibration and scenario analysis of a Groundwater Flow Model**

Geohydrological Data Handling and Groundwater Modelling.

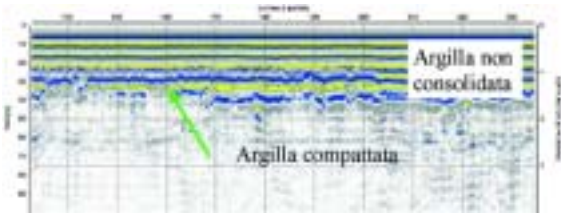
GPR (Ground Penetrating Radar) survey

In all CAMI area we collected GPR profiles using a 100 Mhz monostatic antenna. The electromagnetic waves penetration in these soils was no good because clay of presence (high conductivity). In several zones the GPR detected structures characterized by a lot of scattering and reflections. This result is produced by gravel zones where we can have the springs. The GPR data interpretation has permitted to map all these interesting structures.

Wet zones in Torrate area.
Location of GPR profiles.

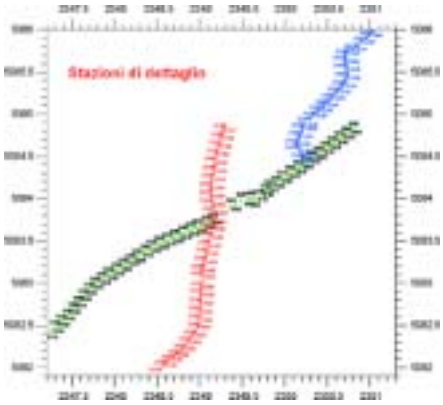


GPR profiles
collected in Torrate.

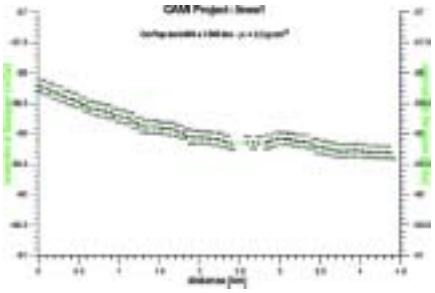


Gravimetric survey

The gravimetric prospecting has the goal to notice the anomalies of the gravitational field of the earth caused by the variations of density of the bodies close to the earth surface. Along the seismic profiles 2D and in proximity of the water wells of the aqueduct, a detailed microgravimetric relief has been performed [a LaCoste-Romberg Gravimeter has been used (L&R)]. 15 gravimetric circuits have been created; a total of 200 gravimetric stations have been set. The position of this station is in accordance with the 3 seismic 2D lines.

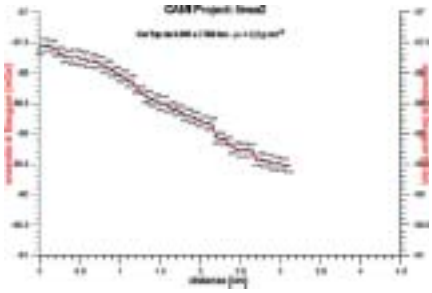


The equidistance among the single stations is of about 50 meters.



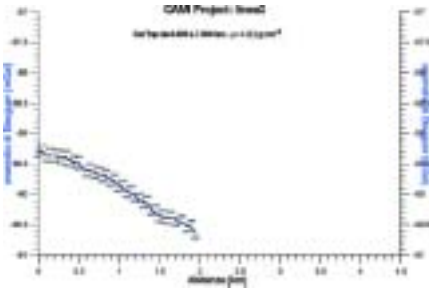
From a qualitative point of view, they are observed:

a) the presence of a generalized diminution of the anomaly of gravity from West toward East, the anomaly is more marked in the interval between the gravimetric stations 1120-1590 with a middle gradient of about –0.400 mGal km-1;
b) the presence of a light indication of "gravimetric tall", having an ampleness of about 0.100 mGals, in the interval between the gravimetric stations 1681-1800.



From a qualitative point of view, they are observed:

a) the presence of one generalized and marked diminution of the anomaly of gravity from South toward North with a middle gradient of about 0.650 mGals km-1;
b) the presence of two discontinuities in correspondence of the stations 2300-2291 and 2201-2190.



From a qualitative point of view, it is observed:

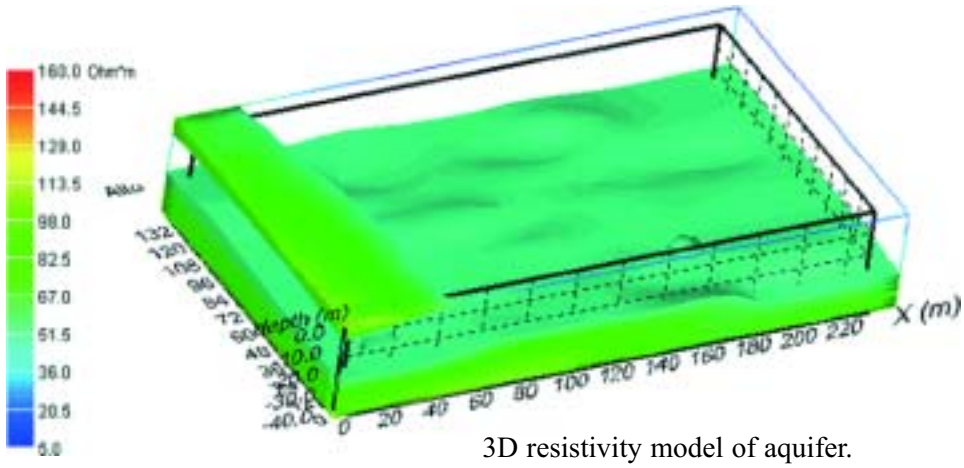
a) the presence of one generalized and marked diminution of the anomaly of gravity from South toward North with a middle gradient of about .0.700 mGals km-1.

The electric tomography for the knowledge of the subsoil

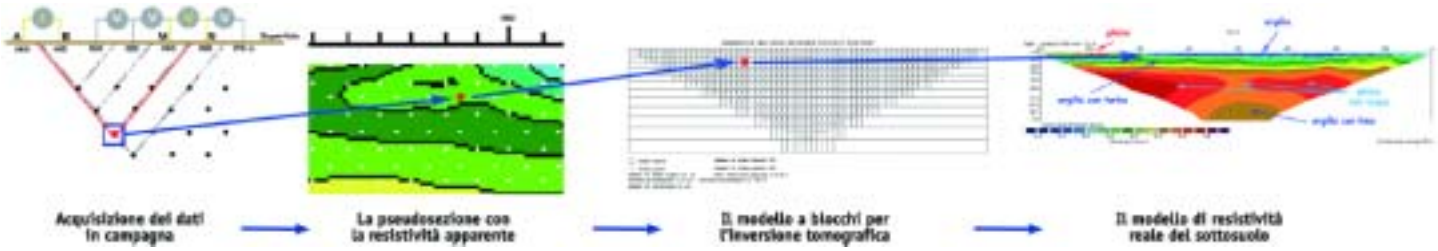
The electric tomography is a geophysical method for the knowledge of the subsoil: rapid, efficient and economic, with limited environmental impact.
Geoelectric prospecting uses measures of direct current to get information on the "apparent resistivity" parameter. This is tied to the resistivity that characterizes the different situations of the subsoil.
The resistivity is mainly affected by the following parameters:

- type of lithology
- degree of saturation of the pore
- porosity
- salinity of the fluid present in the pore
- temperature
- presence of organic substances
- presence of clay
- fractures
- caves

The contrasts of resistivity among the different situations give interesting and profits information on the situation of the subsoil of the investigated site.

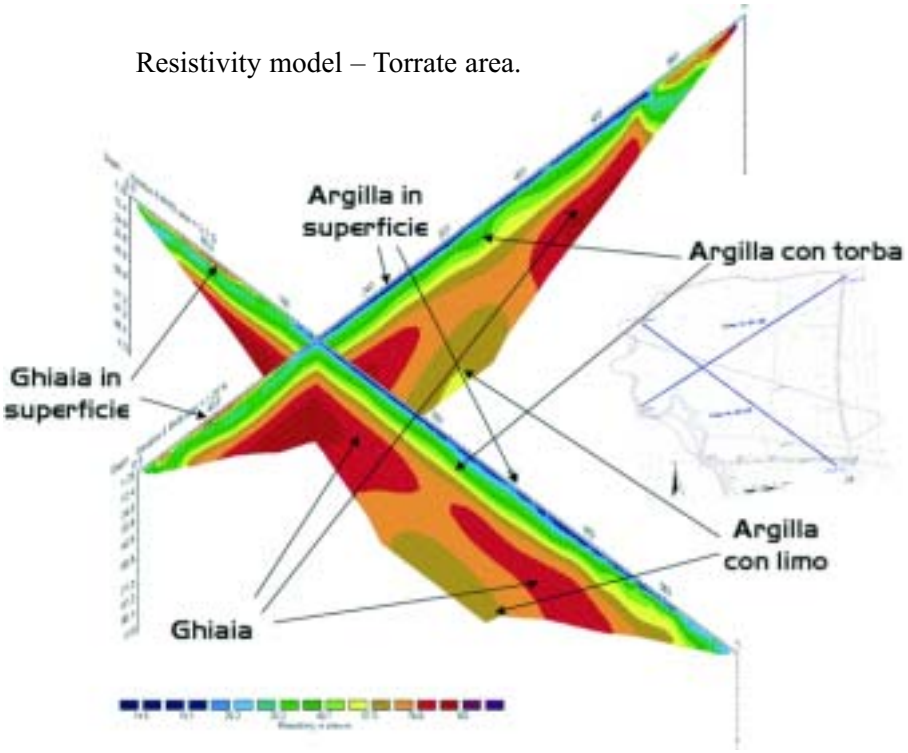


3D resistivity model of aquifer.



The method consists in the injection of a direct current in the ground by two or more "electrodes of current" and in to measure in various points of the ground, with at least two "electrodes of potential", the difference of potential (ddp) induced by the circulation of the injected current.
The distribution of the electric potential on the surface, obtained by the measured ddp values, allows the study of the geometric distribution of the current in the subsoil and therefore of the geometric distribution of the various geological structures having different electric resistivity.

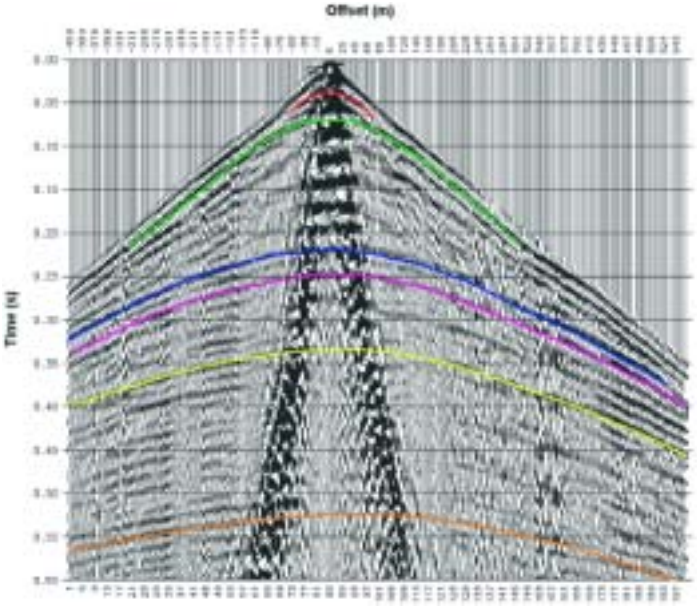
Resistivity model – Torrate area.



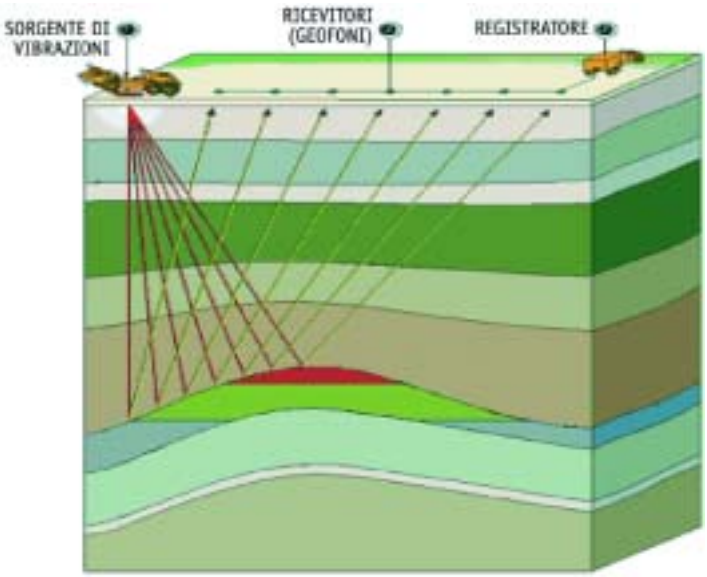
From the years' 20 of the last century the geophysical methods that are based on the electric resistivity have really improved: the instrumentation, used for acquiring the data, from manual and heavy it is passed to light and computer-aided; the interpretation of the field row data has passed from the graphic interpretation for comparison with the answer of simple models, to the computer-aided tomographic inversion with 3D reconstruction of the subsoil.
You get a precise and detailed information of the subsoil, that allows the definition and the monitoring, understood as evolution in the time, of the characteristics of the investigated bodies.

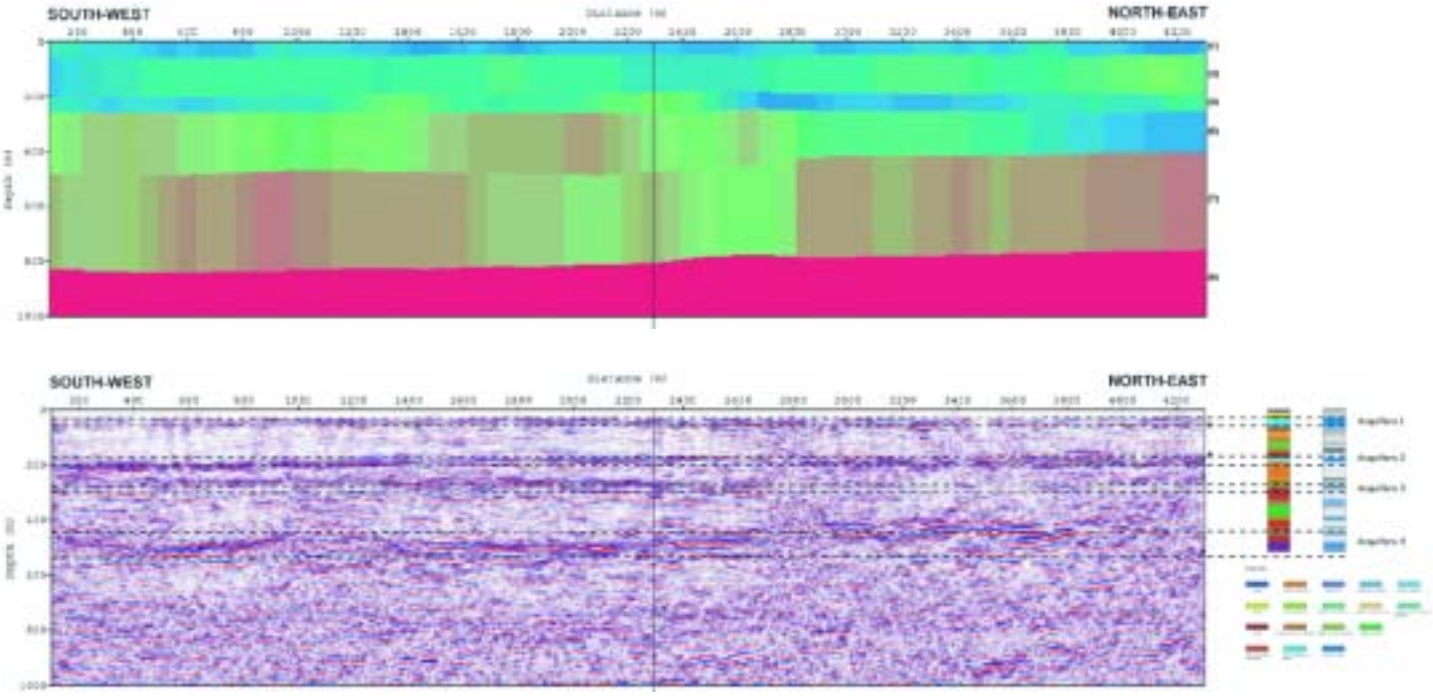
The 2D seismic method applied to the study of the aquifers

In order to investigate the subsurface structures there are many direct methods, which consist in the dig of the ground by drilling boreholes, and indirect methods, which doesn't need to drill and are usually employed for hydrocarbon, mineral and aquifer exploration or engineering applications. One of these indirect prospecting methods is the "seismic reflection" technique, a methodology based on the study of the propagation of the seismic waves (low-frequency acoustic waves) produced by sources like vibrations, striking hammers, etc. The energy generating from these "small earthquakes" propagates through the ground and is reflected in different manners, depending on the physical parameters of the crossed medium. A fraction of this reflected energy travels back to the surface, where is registered by receivers placed at different distances from the source. The energy propagates through the ground following the optic rules. In the figure to the left an example of seismic data is shown.



An example of traces recorded by the receivers after a shot. The coloured lines identify the reflections from the aquifers.

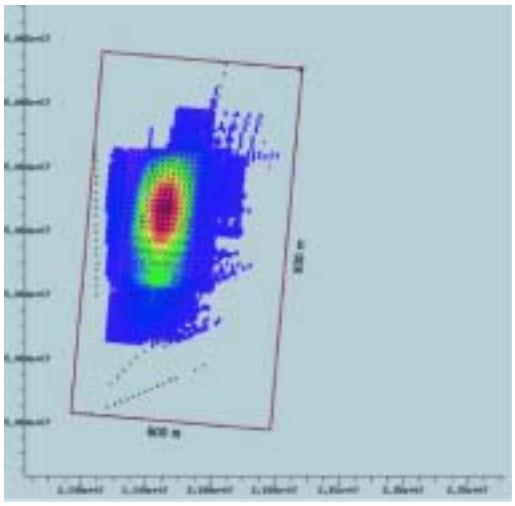


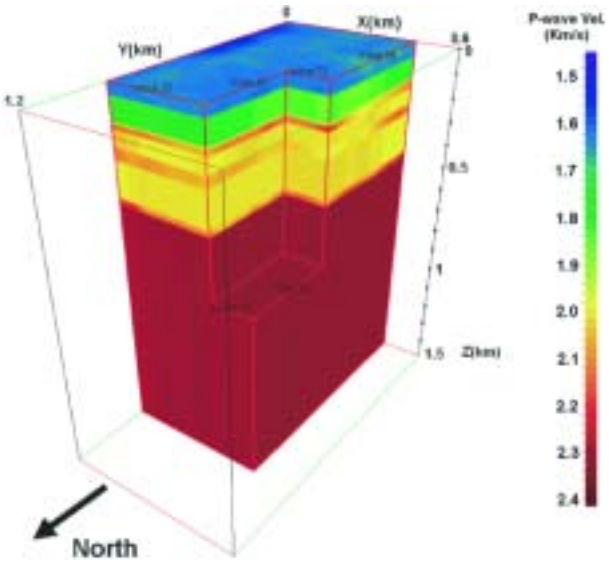


Using both the velocity field and the seismic data, it is possible to obtain a detailed picture of the aquifers in the subsoil. This figure shows a seismic section obtained from the elaboration of the seismic data acquired in an area between S. Vito al Tagliamento and Villotta di Chions (PN).

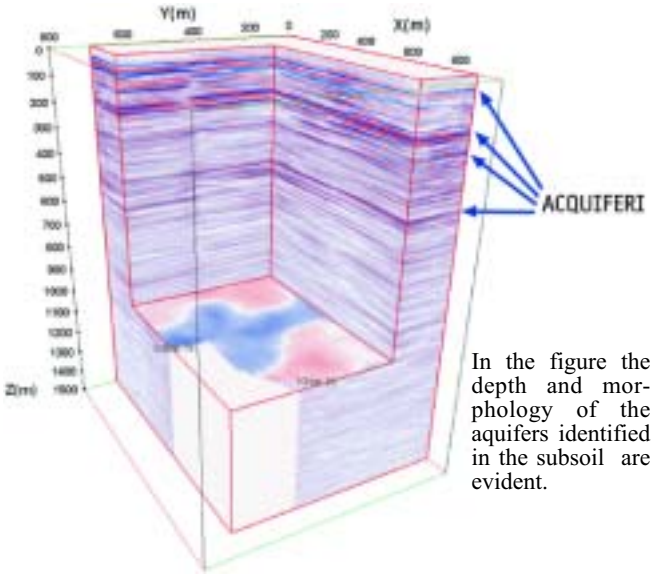
The 3D seismic method applied to the study of the aquifers

The 3D seismic acquisition is based on the same methodology of the traditional reflection seismic (striking hammers, receivers for trace recording, etc.), but allows to study in more detail the distributions of the subsoil properties (i.e., lateral changes of the identified aquifers) in a large area. This kind of acquisition requires a lot of time and instrumentation, restricting thus its field employment.

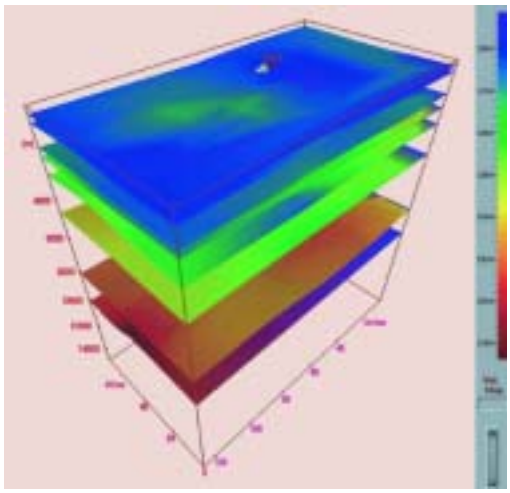




3D velocity field obtained from the tomography of the recorded data.



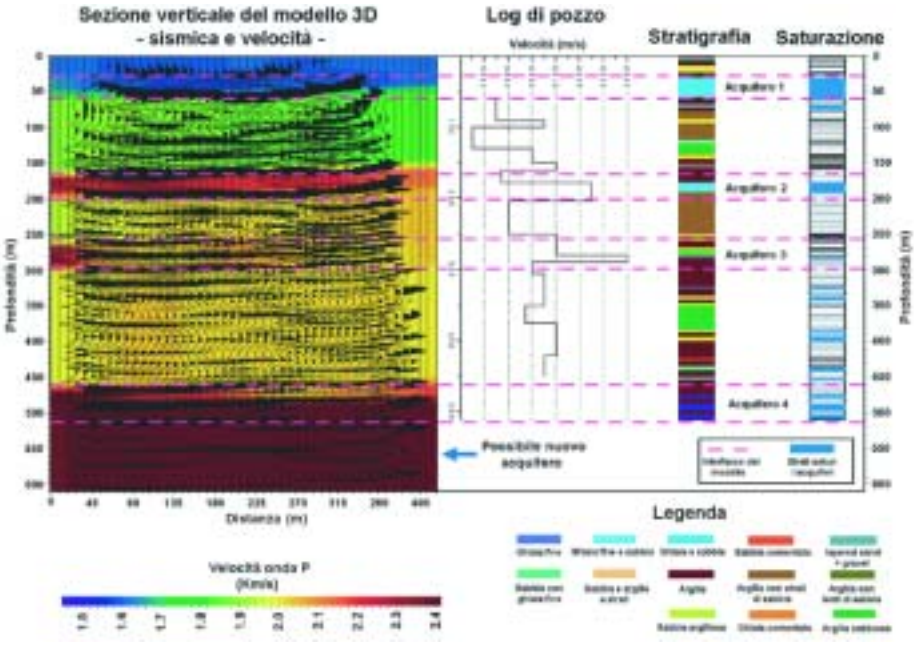
In the figure the depth and morphology of the aquifers identified in the subsoil are evident.



From the analysis of the morphology is possible to define the thickness of the aquifers, their dimension and, thus, their exploitability (economic convenience).

The figure on the right shows a comparison between the results obtained from the seismic survey and the borehole measurements performed near the survey area, on the basis of the seismic results. It's possible to appreciate that the seismic data reproduce with a good accuracy the stratigraphy and the velocity distribution obtained from borehole measurements. The seismic method has limits related to the vertical resolution (thickness definition) that depends on the acquisition parameters and the depth of the target.

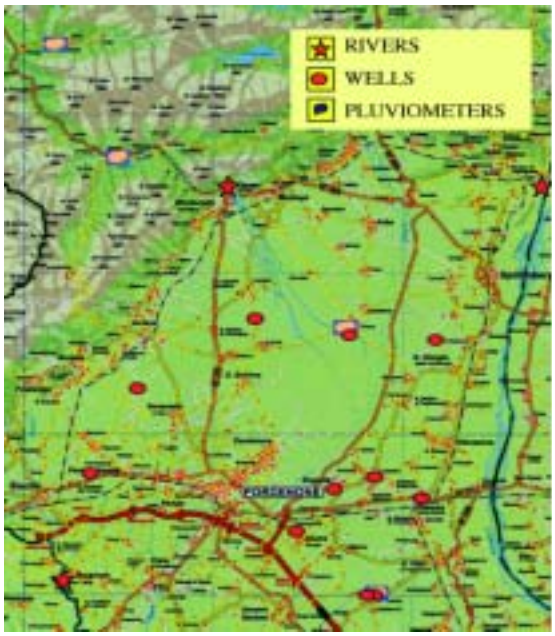
In this case it's possible to identify the correct depth of the aquifers (with an error of about 1 meter) and to detect a thickness of about 5-10 meters.



Aquifer assessment through isotopic geochemistry

Isotopic characterization of circulating waters (meteoric, surface and ground waters) in the recharge zone of the main site of Torrate can define the recharge areas and supply information about the mutual connections between several waters.
The oxygen isotope composition and the radon content have been determined on monthly samples; bi-monthly samples have been measured for tritium activity.

To attain these aims, some dedicated rain gauges have been constructed and installed at different elevations; moreover samples of wells' and rivers' waters have been collected.
Using special instruments on the samples, we have been measured:
a) Oxygen isotope composition;
b) Tritium activity;
c) Radon content.

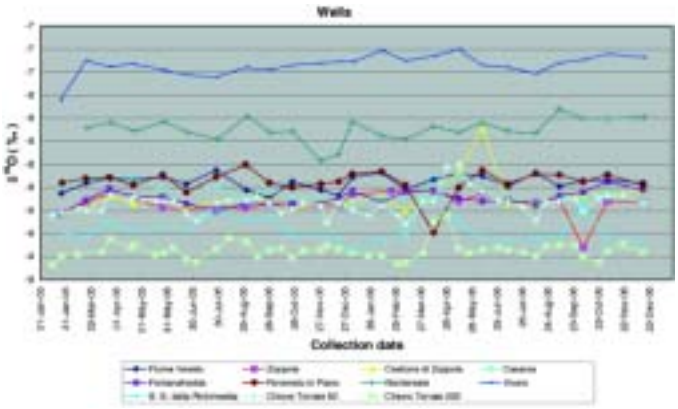


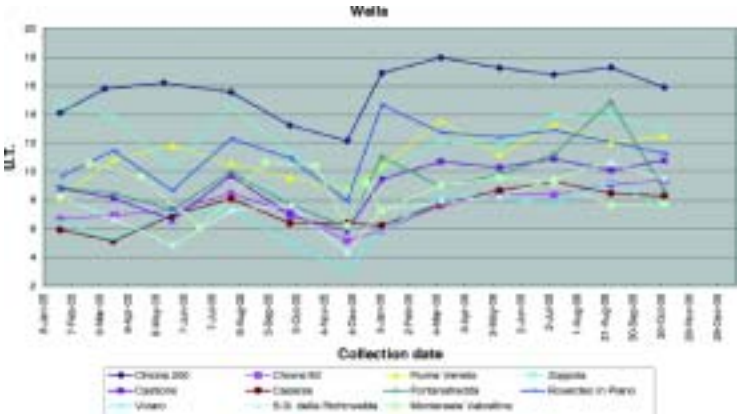
Location of samples collection sites.

Mass spectrometer: used for oxygen isotopic composition measurement.

Low Level Scintillation Counter: used for tritium activity and radon content measurement.

Rain-gauge: used to collect meteoric water samples needed for isotopic analysis.



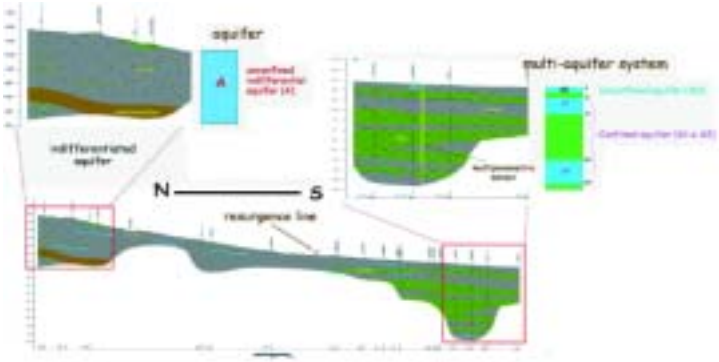


Graphs report variations of oxygen isotopic composition and tritium activity from January 2005 to December 2006 in the selected sites.
These parameters enable to define the mean altitude of the aquiferous recharge areas and the residence time of the ground-water.

University of Ferrara
Department of Earth Sciences

Progetto CAMI

Qualitative and dynamic characterization of the aquifer based on geophysical and geochemical integrated methodologies



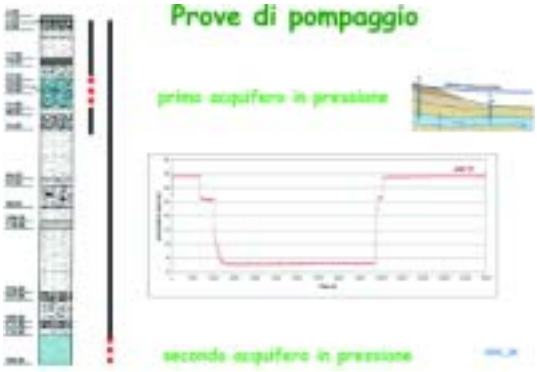
The University of Ferrara has provided a hydrogeological conceptual model of the aquifer system and has contributed to the set up of a geophysical and geochemical integrated methodology allowing to understand and evaluate the behaviour of the aquifers existing in the investigated area. These goals have been achieved based on pumping tests, installation of a multiparametric probes and the geophysical parametrization of the subsoil with non-invasive methods (magnetotelluric and TDEM methods).

In order to define the aquifer units developed in the subsoil, stratigraphic data have been collected, omogenised and included in database. In particular, this research focused on the western side of the Tagliamento River in an area between Spilimbergo and Torrate, north and south respectively.

Based on specific stratigraphic logs and using hydrogeological criteria, several hydrogeological sections have been reconstructed to define the hydrogeological conceptual model.

The data analysis emphasised that the investigated area is characterised by the occurrence of two distinct hydrogeological systems developed respectively north and south of the resurgence line.

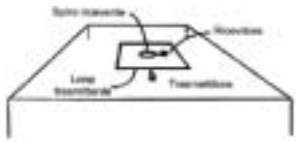
In order to define the hydrodynamic and hydrochemical behaviour of the aquifers, a measurement campaign has been performed. During the field work, we directly measured the piezometric level as well as the chemico-physical parameters (pH, electrical conductivity, temperature) from numerous boreholes. Also collected water samples for a laboratory confirmation of the parameters and to carry out chemical analyses for selected boreholes.



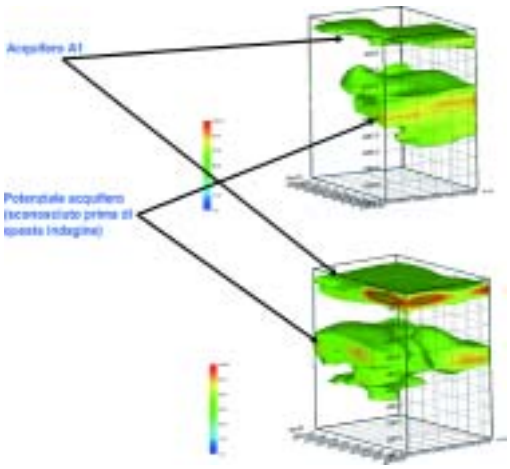
Finally, the installation of multiparametric sensors in the Torrate aqueduct network, will enable us to a continuous monitoring of the water depth and of the chemical-physical parameters of the aquifers system and therefore to understand the influence of the explotation of the aquifer on the qualitative and quantitative characteristics of the whole system.

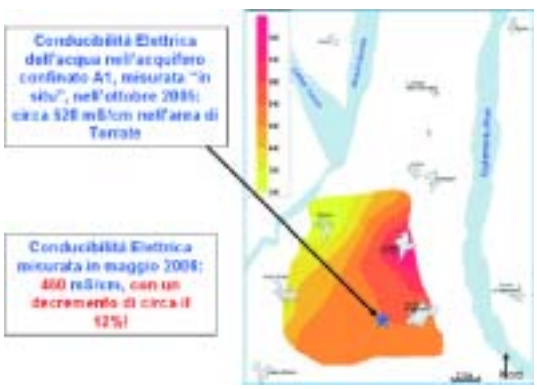
The "TDEM" electromagnetic method for deep groundwater investigations

A quick and efficient method to characterize the deep distribution of the electrical resistivity within the studied area is the so-called TDEM (Time-Domain Electromagnetic Method). A 3D image of the subsurface resistivity distribution can be obtained by carrying out a sufficient number of measurement points. This distribution is then correlated with the petrographic-geochemical characters of the aquifers and with the eventual geotectonic anisotropies of the area; the repetition of the measurements allows to monitorise quail-quantitative evolution of the aquifers.



The TDEM method of investigation
Above: the sketch of the "sounding": a pulsed current is fed in a generally square loop of wire isolated from the ground. With the receiver coil (in the picture) the induced magnetic field is measured, which depends on the resistivity distribution below the transmitter loop.



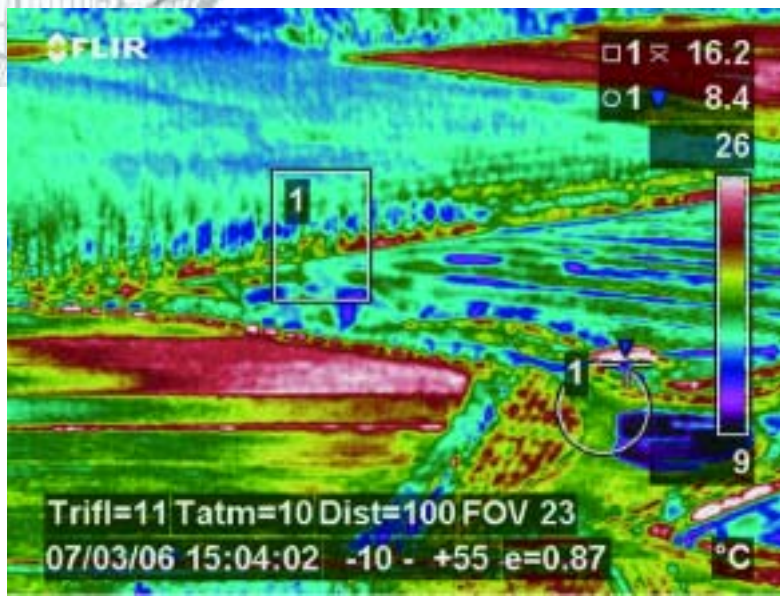


Integrated application of high resolution and fast geophysical methods: airborne thermography and GPR on the spring barrier system for the modelling of flow and evaluation of vulnerability

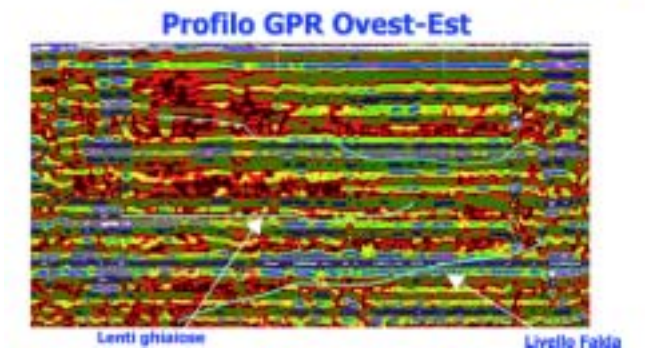
The main goal of this task is the application of a fast and precise methodology able to define the hydro geological mechanisms responsible for the formation and existence of a spring barrier system. It can be obtained by the application of thermography for the study of the thermal anomalies determined by the rising of spring waters.
This survey has bee supported by a GPR investigation for the mapping of the shallow stratigraphy aimed at the reconstruction and correlation of the levels allowing the water movements.

Flight paths of the airborne thermography

The typical landscape of the spring barrier area of Torrate.



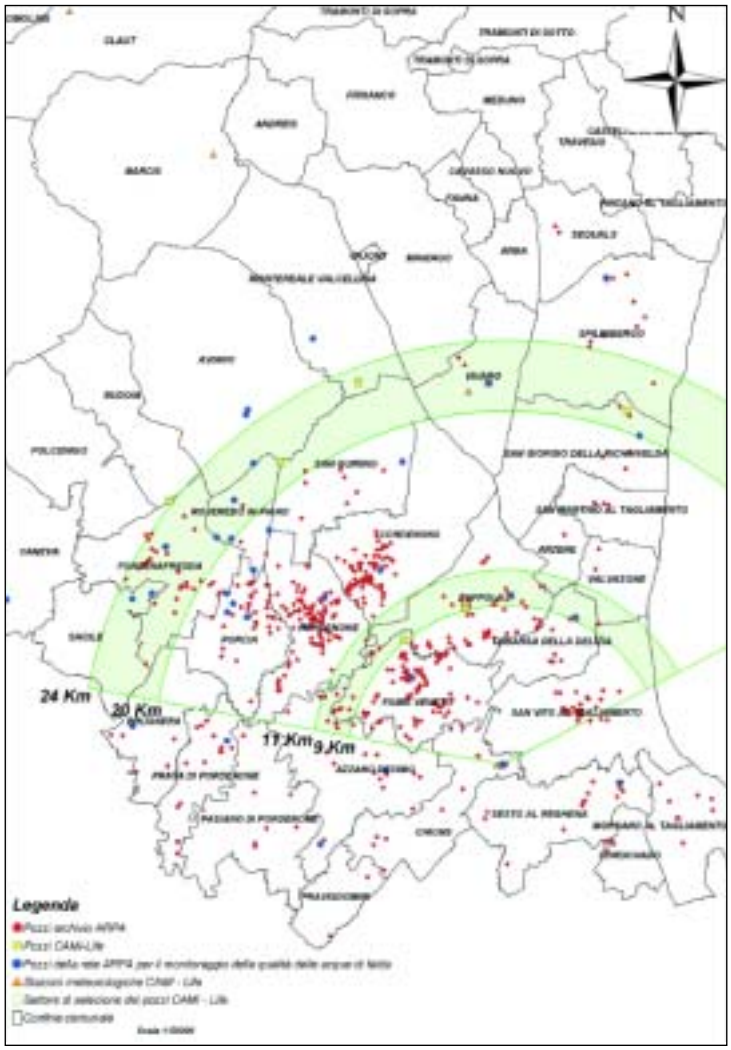
Ground Penetrating Radar (GPR)



The aim of the thermography is the identification of the part of the subsoil where the groundwater is approaching the surface.
This can be obtained by studying the thermal anomaly determined by the presence of water; water is in fact warmer than the soil in winter and colder in summer. This effect determined a “inverse” thermal anomaly (warmer in winter colder in summer) indicating the presence of water close to the soil surface.

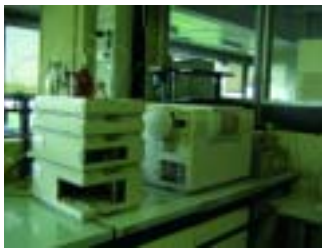
ARPA Environmentl Regional Protection Agency of Friuli Venezia Giulia – Local Department of Pordenone

Acquisition and elaboration of deepwater analytical data
Acquisition and elaboration of meteorological data
Taking of rain and well samples
Spread of the results



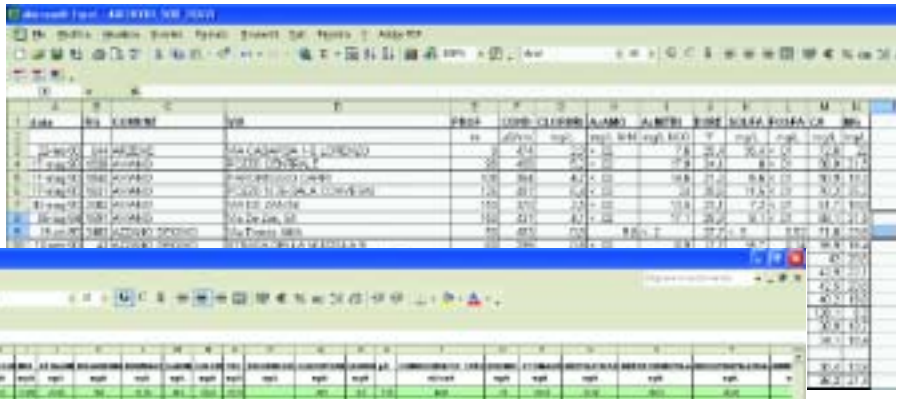
The ARPA Department of Pordenone supplied analitical data about groundwater composition in the Pordenone province preparing a data base with 500 well chemical analysis. The monthly sampling of deep water and rain to perform isotopic analysis by Trieste university aimed to create a correlation model about deep water circulation in the studied area.




With the aim to prepare a base about the situation of aquifers in the Province, ARPA collected chemical and pollution data of more than 500 wells in the 1994-2004 period with information about depth and geographic position.

Chemical characteristics of water samples.




Providing data for the updating of the geohydrological database, assessment of the geohydrological model, improving the knowledgement about the ground water system

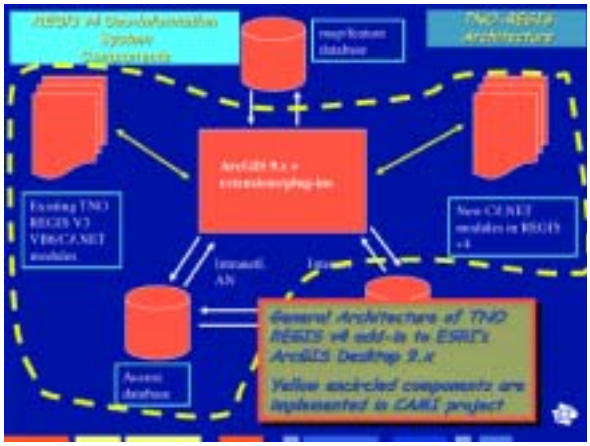
ABL provided a collection of historical data, enclosing stratigraphies and pump test on "Torrate Area", and supplied logistic assistance for geophysical and geochemical tests; moreover, ABL helped to assess and disseminate the final results.

ABL has an experience of 50 years in managing the water resource and using state-of-the-art tecnologies in building and mantaining the water system. The project will allow ABL to better plan the repartition of water on different uses (civil, agricultural, industrial), to evaluate the impact on water resources of new industrial and civil settlements, to quantify the ground water reserve).

In order to verify the outcomes of the seismic and geo-electric experiments and the possibility of exploiting for potable use the acquifers placed beyond 200 metres under the ground, the Water Company drilled a well deep 500 m.

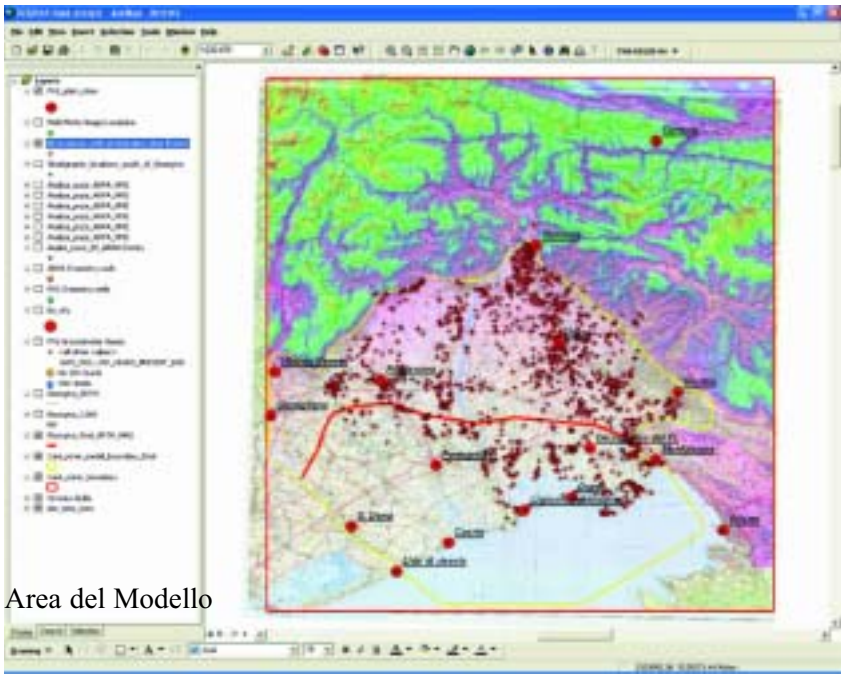
Development and implementation of a Regional Geohydrological Information System (REGIS)

REGIS (REgional Geohydrological Information System) is a powerful system to support groundwater management anywhere in the world. It convers all data storage and processing requirements to analyse and visualise the (geo)hydrology and groundwater system of an area, from a local to a regional scale.
A database (DBMS) has been created in order to store all collected data [(geo)hydrology data], using a data model adopted from the national TNO groundwater database. Common GIS software packages (ESRI) are used to query the database and generate maps. In this project the TNO REGIS software (a plug-in for ArcGIS desktop) has been used to analyse the stored groundwater data like level time series and hydrochemistry.



REGIS v4 Architecture.

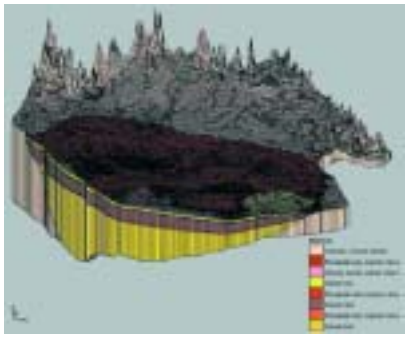
Development, calibration and scenario analysis of a Groundwater Flow Model



Area del Modello

Overview of CAMI project area and collected borehole data.
Groundwater Model Area.

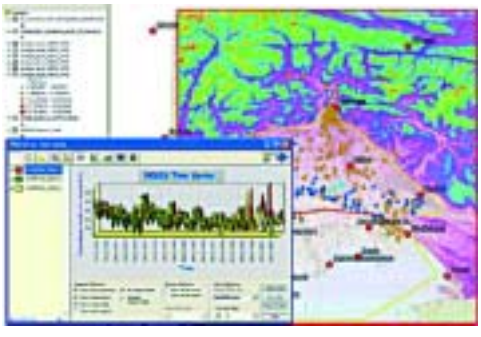
The detailed stratigraphy of some 1800 boreholes, stored in the database, has been used to determine the position of (sub)regional clayey horizons in the predominantly coarse grained aquifers.
The elaboration of the collected data has allowed us to characterize the subsurface and to estimate the hydraulic parameters of the regional aquifers.
For the numerical groundwater modelling commercial software packages like GMS 6.0 (Groundwater Modelling System from EMS-i) has been chosen.

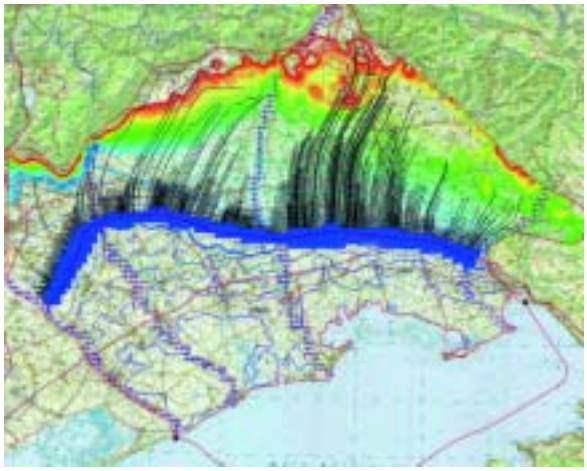


Solid model with GMS 6.0

The first step consisted of creating a 3D solid model of the geological layering and structures in the subsoil and by identifying the main aquifers in the Plio-Quaternary deposits. Steady-state simulations have been performed revealing new exciting information about the regional groundwater flow.
It is expected that the model (developed in MODFLOW) together with the database will become one of the tools in the management of the groundwater resources in the Friuli plain the nearby future.

REGIS v4 groundwater level time series.





Pathlines of groundwater flow.

Water-bearing characterization with integrated methodologies

CAMI Project

Project Number:
LIFE04 ENV/IT/000500

LIFE Project Name:
WATER BEARING CHARACTERIZATION WITH INTEGRATED METHODOLOGIES

Project location:
ITALIA IT – FRIULI VENEZIA GIULIA AND VENETO

Beneficiary:
ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE – OGS

Postal address:
BORGO GROTTA GIGANTE N° 42/c, 34010, SGONICO (TRIESTE)

Telephone:
+39(0)4021401
Fax:+39(0)40327307

Project start date:
01/12/2004

Project end date:
31/05/2007

Total budget:
€ 1.172.659,00

EC contribution:
€ 560.869,00

Project Website:
http://www.cami-life.net

The **National Institute of Oceanography and Experimental Geophysics – OGS** is a state-run research institution operating under the jurisdiction of the Italian Ministry for University and Research (MUR). Its mission is to promote, co-ordinate and carry out, by itself or in collaboration with other private or public-sector national, european or international bodies, scientific research in the fields of Oceanography and Applied Geophysics.

The Institute is constituted by the following research departments:

- **Biological Oceanography** (BIO),
- **Development of Marine Technology and Research** (RIMA),
- **Geophysics of the Lithosphere** (GDL),
- **Oceanography** (OGA),
- **Seismology** (CRS).

ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE
Borgo Grotta Gigante 42/C – 34010 Sgonico (Trieste) – Tel. +39 04021401 – Fax +39 040327307
Via Treviso, 55 – 33100 Udine – Tel. +39 0432 522433 – Fax +39 0432 522474
http://www.ogs.trieste.it
mailbox@ogs.trieste.it
N. verde 800844944

© 4/2007 - OGS, gruppo GEBA – *Realizzazione:* Alessandro Affatato – *Designer:* Nino Bon – *Stampa:* Stella – Trieste