LINATE AIRPORT GEOTHERMAL PROJECT
EVALUATION OF THE UNDERGROUND HYDROGEOLOGICAL AND GEOTHERMAL RESOURCES

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ABSTRACT

A detailed study of the geothermal reservoirs existing in the subsurface of the Linate (Milano - Italy) airport area was carried out in the frame of a geothermal project aiming at meeting the heat needs of the airport installations (space heating, de-icing and de-misting). The inventory and interpretation of all available information allowed the assessment of the hydrogeological and geothermal characteristics of the existing aquifers, namely the shallow, intermediate and deep aquifers. Mathematical models were applied for the definition of the aquifer thermal and hydrodynamic behaviour. A thorough economical analysis was carried out for the optimisation of the geothermal fluids exploitation and relevant technologies. Furthermore, the study of the best system to store the interseasonal heat by means of injection in the shallow aquifer was carried out. The results allowed to propose reliable technico-economical solutions for the aquifer exploitation and for the storage of the interseasonal heat.

1. INTRODUCTION

This paper describes the results of the investigations carried out for the evaluation of the geothermal reservoirs existing in the subsurface of the Linate airport area (Milano - Italy). The project was undertaken by Lombardia Risorse SpA - Milano, with the financial contribution of the European Community Commission.

The objective of the work was to evaluate the technico-economical feasibility of the project, which aims at meeting the heat demand of the airport installations, including space heating of airport facilities, runways de-icing and de-misting, by means of the underground low-enthalpy geothermal resources. The following operations were carried out:

- inventory of all available information concerning the existing aquifers: deep hydrocarbon well logs from AGIP SpA, shallow water wells from local Public Authorities, from private files and from published and unpublished works
- analysis of the hydrogeological and thermal characteristics of the aquifers and assessment of the relevant exploitation possibilities: data elaboration and interpretation in order to frame the study area in the regional stratigraphical and structural picture, field testing, thermal logs, outline of the reservoir Characteristics in terms of thermal and hydrogeologic conditions, hydraulic parameters and potential productivity
- optimisation of the geothermal fluid production and exploitation technologies: hydrothermal and hydrodynamic simulations considering alternative exploitation schemes, economic analysis
- feasibility study of the aquifer seasonal heat storage.

2. GEOLOGICAL OUTLINE

The Linate Airport (Fig. 1) is located east of Milano (northern Italy), and its southern boundary falls a few hundred meters from the existing geothermal doublet of Metanopoli. The general geological knowledge of the study area is supplied by seismic data and hydrocarbon wells dnlled by AGIP in the last forty years. Shallow- and intermediate-depth wells for water supply are also present, allowing us to detail the characteristics of the shallow aquifers. The location of the wells is shown in Fig. 1.

The general lithostratigraphic conditions in the eastern Milano area are shown in Fig. 2. The deeper hydrogeologic target is confined to the bottom of the Late Miocene sediments. The formations penetrated by the hydrocarbon wells belong to a sedimentary sequence consisting of sand, gravel and clay. The following formations or groups were defined, from bottom to top:

- **Gallare - Gonfolite Groups**

Age: pre-Messinian (early Miocene to Messinian in the restricted study area).
Lithology: marl and clay with thin layers of silty sandstone; scarce rounded pebbles.
Thickness: the maximum drilled thickness is about 2000 m.

- **Sergnano Formation**

Age: Messinian (Late Miocene).
Lithology: polygenic pebbles conglomerate, from loose to partly cemented.
Thickness: the prevailingly continental environment of deposition and the tectonic-erosion phenomena which affected the formation determined a very variable thickness, from zero or few meters up to more than 900 m.

- **Colombacci Formation**

Age: Late Messinian.
Lithology: Prevailing clay with erratic intercalations of sand, sandstone and conglomerate. The base of the formation is generally coarse and transgressive on the underlying Sergnano Formation.
Thickness: about 250 m in the southern sector. The unit pinches out towards the north.

- **Santerno Formation**

Age: Pliocene. This unit can be subdivided into two members, as follows:

Ripalta Member
Age: Lower to Middle Pliocene.
Lithology: clay with thin intercalations of silt and fine sand.
Thickness: from 220 to 475 m; 350 to 450 m in the restricted study area.

Pandino Member
Age: Middle to Upper Pliocene.
Lithology: alternations of clay and fine sand.
Thickness: from 250 to 330 m in the southern sector, markedly decreasing northwards.

- **Asti Formation**

Age: Upper Pliocene - Pleistocene.
Lithology: fine clayey sand with thin clay alternations. Presence of medium-coarse sand and pebbly levels in the upper part of the formation.
Thickness: from 500 to 950 m.

- **Continental Formations**

Age: Holocene.
Lithology: this includes a wide range of lithologic types deposited in different environments, prevailingly continental. In the restricted project area it is possible to separate a lower part, where sand and clayey sand prevail, from an upper part where alluvial coarse sand

and gravel are widespread.
Thickness: average 300 m, with strong local variations.

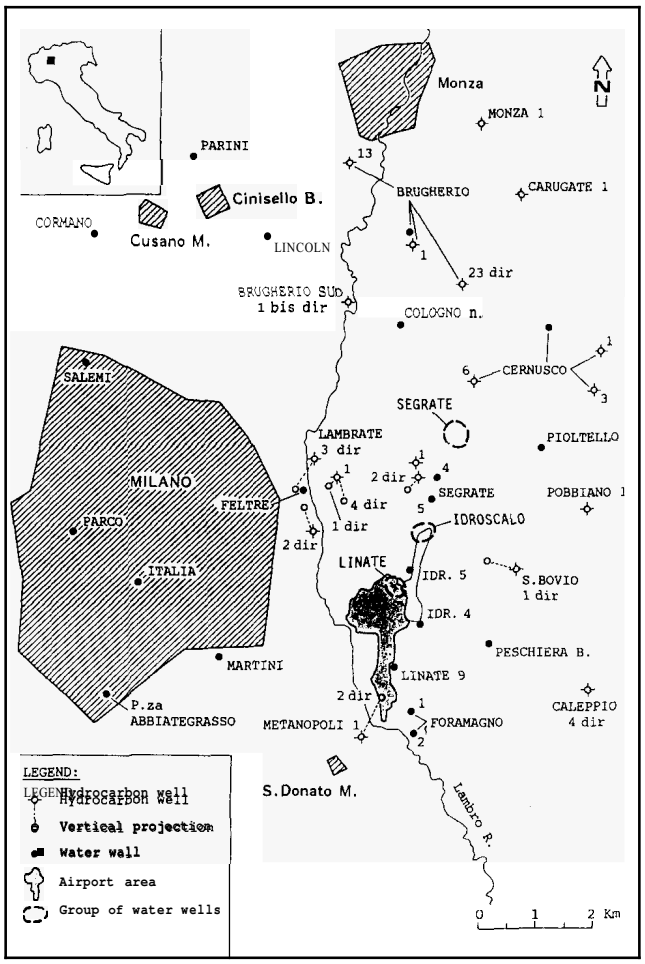


Fig. 1 - General position map

3. THE AQUIFERS OF THE LINATE PROJECT AREA

Three main aquifers, each of them including one or more water bearing horizons, were recognised within the buried lithostratigraphic sequence. These are, from the top (Fig. *2):*

- **Shallow aquifer:** in the continental Quaternary gravel and sand. The relevant reservoirs are characterised by cold water temperatures and preferential destination to civil purpose. It represents a favourable target as far as the aquifer seasonal heat storage is concerned.
- **Intermediate aquifer:** in the Plio-Pleistocene clayey sand. It can be subdivided into two reservoirs, both of possible geothermal interest:
  Fresh-water upper reservoir, in the Pleistocene Asti sand.
  Salt-water lower reservoir, in the late Pliocene Asti sand and in the Pliocene Pandino member.
- **Deep Aquifer:** in the Messinian Sergnano gravel.

Information about thickness, attitude and geometry of these aquifers within the project area were supplied by seismic interpretation and well-log correlation. The general aquifer geometry is shown by the cross-section of Fig. 3, from Segrate to the north to Metanopoli to the south. The same cross-section, drawn at a different scale in Fig. 4, shows a detailed picture concerning the shallow aquifer. The evaluation of the hydraulic parameters and potential productivity was carried out by means of the results of several pumping tests, as far as the shallow aquifer is concerned, and by means of the extrapolation of few measured data, as far as the intermediate and deep aquifers are concerned. The extrapolation was carried out on the basis of a detailed quantitative interpretation of geophysical well logs. The main characteristics and parameters of the aquifers are hereinafter described, starting with the deepest.

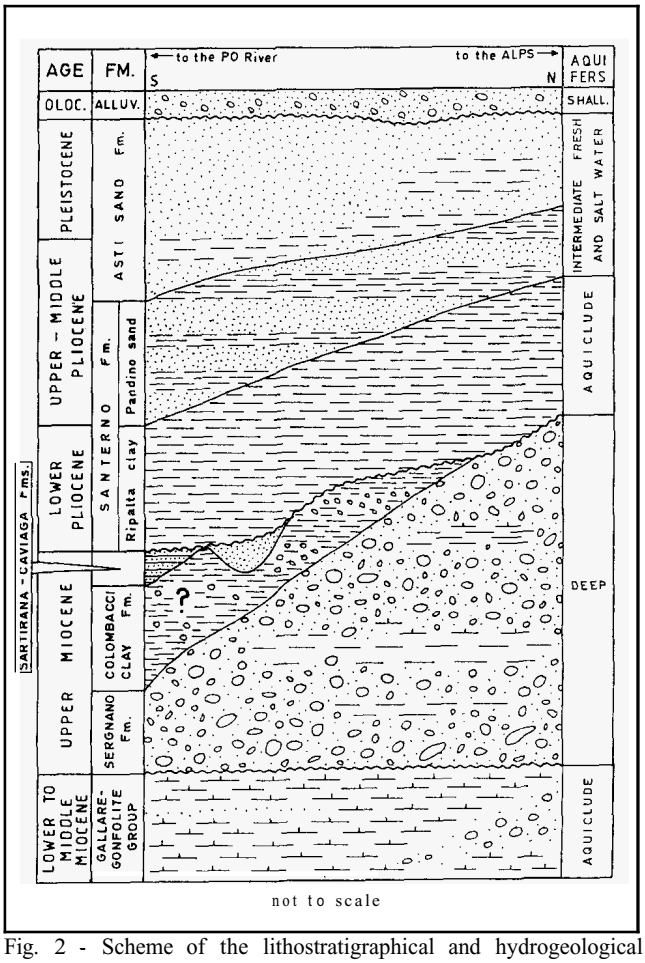


Fig. 2 - Scheme of the lithostratigraphical and hydrogeological conditions along the Milano meridian (after AGIP, modified)

3.1 Deep Aquifer

The deep aquifer reservoir is identified by the Sergnano gravel Formation of Messinian age. Seismic and stratigraphic evidence shows that the gravel deposition took place during two main sedimentary cycles with different facies characteristics: the first cycle (lower) deposits are comparatively thin but more or less continuous, the matrix is argillaceous; the second cycle (upper) deposits are discontinuous but the coarse sediments are fairly clean.

The top of the second cycle deposits shows up as a terraced surface with a steep scarp whose southern edge may be seismically outlined, trending **E-W,** from Milano toward east over a distance of several kilometres. This fact mainly involves a sharp reduction of the gravel thickness in the south of the scarp, where the second cycle deposits are from very thin to missing. This is confirmed by the results of the Metanopoli geothermal doublet, in the southern sector of the project area, where only few meters of clean gravel were encountered.

It was shown that the interval identifying the deep reservoir is very thin and probably scarcely productive over the most part of the airport area. More favourable conditions are only found at its northern edge. These are the followings:

- Top of the aquifer: from 1300 to 1400 m b.s.l.; i.e. from 1400 to 1550 m b.g.l.
- Thickness of the aquifer: 300 m gross pay and about 150 to 200 m net pay. The exploitation of all the formation pay intervals would require a 1700 to 2000 m deep well.
- Reservoir parameters: a wide range of permeability values can be expected depending on the argillaceous content of the gravel **matrix** and on the sand/gravel ratio of the pay intervals. Average values of 100 to 250 md can be foreseen in the best sector, but even higher values, from 500 to 1000 md, confined to some better intervals, are not unlikely.

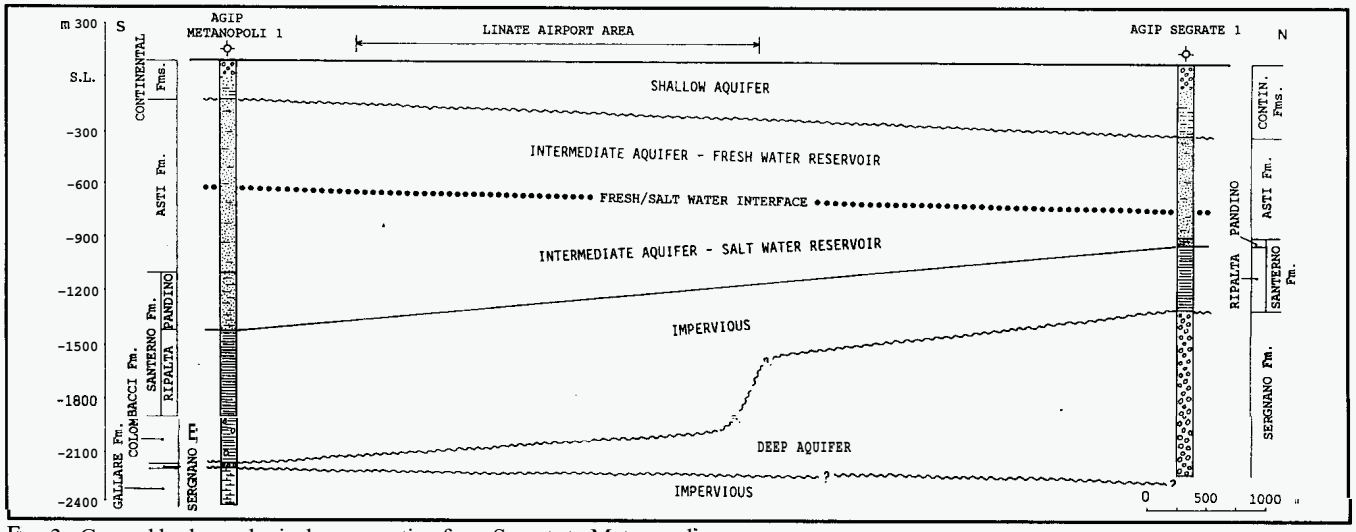


Fig. 3 - General hydrogeological cross-section from Segrate to Metanopoli

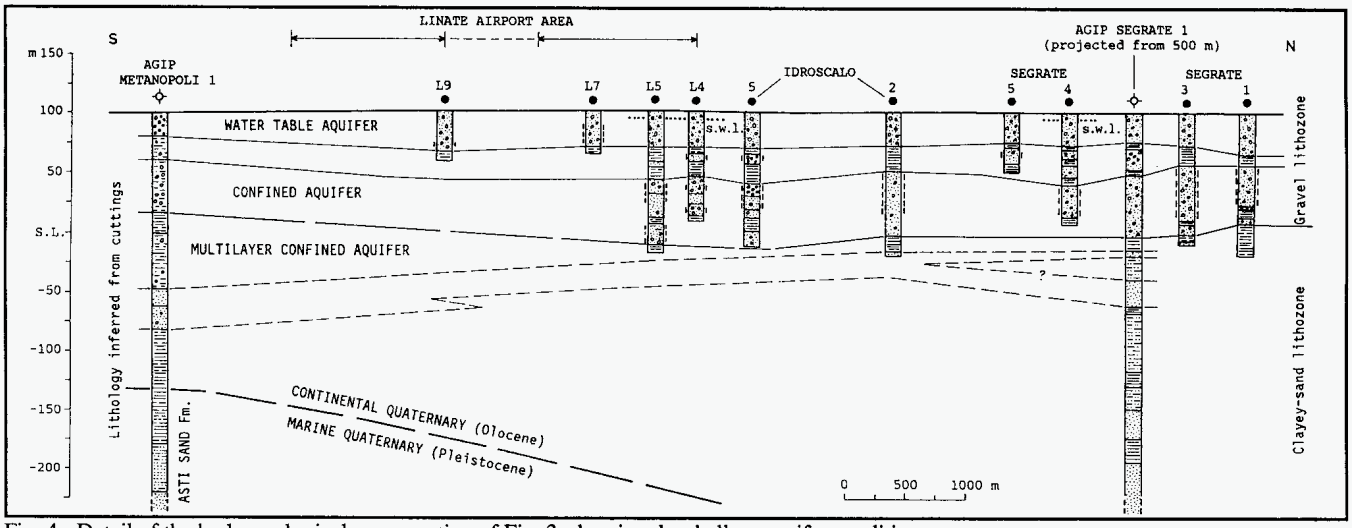


Fig. 4 - Detail of the hydrogeological cross-section of Fig. 3, showing the shallow aquifer conditions

The resulting Kh will probably range from 15 to 50 Dm. In the worst conditions (missing of the cleaner gravel horizons), the formation permeability, determined by means of production tests, ranges from 15 to 50 md. The effective porosity values range from 15 to 25% in the sand and from 8 to **19%** in the gravel.

- Production chemistry: data from wells close to the project area show a reservoir water salinity of about 70 NaCl g/l. Production of methane associated with salty water is foreseen even if the gas/water ratio is not predictable. Moderate corrosion rates and 1-2 mg/l suspended solids at the well head can be foreseen.

3.2 Intermediate aquifer

An upper fresh-water bearing reservoir and a lower salt-water bearing reservoir were singled out within the intermediate aquifer. Quantitative data on permeability and productivity **of** these reservoirs are virtually missing; however, in the frame of the project, attention has been paid also to these horizons due to the shallower depth and mainly to the remarkable restriction of favourable areas for the exploitation of the deep reservoir.

The evaluation of the formation characteristics was carried out by means of a thorough interpretation of the available sets of well logs. The following steps were followed:

- a preliminary qualitative interpretation, which allowed to distinguish the "not impervious" sand or clayey sand intervals from the markedly impervious clayey ones
- a quantitative interpretation of the "not impervious" layers. This allowed an estimation of the net pay thickness and of the shale content of each layer at the northern (San Bovio site) and at the southern (Metanopoli site) edges of the airport area. The evaluation was carried out on the basis of the following log values: HRT (High Resolution Temperature), γ ray (API units), porosity (% porosity units corrected from the log readings of CNL, Formation Density and SONIC), R_{ILD} and R_{SFL} (corrected resistivity values from Induction **Log** Deep and Spherically Focused **Log),** F_A (apparent formation factor), mud cake thickness
- a prudent estimation of the Permeability values of the net pay layers, allowed by a permeability/shaliness variation trend which was tentatively reconstructed on the basis of the few permeability values determined by means of production tests or core analyses.

Salt-waterreservoir

- Top of the reservoir this **is** defined by the fresh-brackish water interface. Above the interface, the formation water **salinity** is less than 2 **g/l**. The surface was contoured **on** the basis of the AGIP hydrocarbon well information, showing a depth ranging from *550* m b.s.l. to the south to 750 m b.s.l. to the north of the study area, i.e. from 660 to 870 m below ground level.
- Thickness of the reservoir: the bottom of the reservoir is defined **by** the Santerno Clay top. The gross thickness is about 400 m along the northern edge of the airport area, and 850 m along the southern one. ***So,*** the exploitation of all the formation pay intervals would require a 1300 to 1500 m deep well. The net thickness varies from 150 m to the north to 380 m to the south.
- Reservoir parameters: on the basis **of** the clay content, permeability values from 15 to 25 md to the south, and from 15 to 40 md to the north, were estimated for the cleaner layers of the reservoir. These figures give rise to a Kh of about 3200 mdm along the northern edge of the project area and 7600 mdm along the southern one. A prudent

estimation of 8% effective porosity was made in order to supply an input value for the mathematical model simulations.
• Production Chemistry: the water salinity shows an increase towards the depth with values ranging from 2-3 g/l to more than 40 g/l. Methane associated with water can be considered negligible.

Fresh-water reservoir
• Top of the reservoir: there is no particular horizon which marks the top of the intermediate aquifer fresh water reservoir. An average depth of 300 m b.g.l. was established, as the upper section is exploited for civil use.
• Thickness of the reservoir: the bottom of the reservoir is defined by the fresh/brackish water interface. The gross thickness is about 550 m along the northern edge of the airport area, and 350 m along the southem one. *So,* the exploitation of all the formation pay intervals would require a 650 to 850 m deep well. The net thickness varies from 170 m to the north to 90 m to the south.
• Reservoir parameters: permeability values from 25 to 120 md to the south, and from 20 to 100 md to the north, were estimated for net pay layers of the reservoir. This gives rise to a Kh of about 5300 mdm along the northern edge of the project area and 7400 mdm along the southem one. The effective porosity may be approximately 10%.
• Production chemistry: water salinity should be less than 2 g/l.

3.3 Shallow aquifer

This is the multilayer aquifer complex, consisting of prevailingly continental deposits, extending from g.l. to the depth of about 300 m. It includes a number of permeable layers, separated by argillaceous intercalations, which are saturated by fresh water and exploited by numerous wells for civil, industrial and agricultural use. Two lithological units, at average grain-size decreasing downward, can be distinguished within the continental sequence, from the top:

• the "gravel lithozone", from g.l. to the depth of about 100 m, consisting of gravel and medium-coarse sand of recent fluvial or fluvio-glacial origin, with subordinate silty-clayey intercalations. In this unit, an upper unconfined aquifer and a lower semi-confined to confined aquifer are found
• the "clayey-sand lithozone" consisting of clayey sand and sandy clay with several intercalations of comparatively clean sand, fine- to coarse-grained, and some thin gravel layers. The sediments of this unit, extending from 100 to about 300 m b.g.l., are of continental origin in the upper part, with frequent lacustrian episodes; in the lower part they become transitional and gradually pass to the marine facies of the Asti sand. The coarse layers form a multilayer confined aquifer.

The characteristics of the three main aquifer levels, which alltogether form the shallow aquifer, were determined by means of field operations and of bibliographic data collection.

Unconfined aauifer (Gravel lithozone)
It extends from g.l. to a depth of about 30 m, where the first silty-clayey layer is found. The attitude of the water table shows that the regional groundwater flow is from NNW to SSE, with an average hydraulic gradient of 3.5 - 5.0 x 10^{-3}. The average yearly fluctuation of the water table level is about 1.5 m. The aquifer is formed by clean coarse gravel and is characterised by very good production parameters: well yields range from 40 to 100 l/s with specific capacity from 20 to 50 l/s/m. In the airport area, the following average parameters were calculated:
Permeability - 2 x 10^{-3} m/s
Net pay - 25 m
Transmissivity - 5 x 10^{-2} m^2/s
Storage - 1 x 10^{-2}

Semi-confined to confined aauifer (Gravel lithozone)
It extends from 50 m b.g.l. to a depth of about 100 m. The piezomemc level rises up to 5-10 m below g.l. and is about 2 m deeper than the water table. The regional groundwater flow is from NW to SE, with strong local variations due to the depression cones of Milano urban area. The average hydraulic gradient is 1.5 x 10^{-3}. The aquifer is formed by coarse sand and gravel and is characterised by the following average parameters within the study area:
Permeability - 7 x 10^{-4} m/s
Net pay - 40 m
Transmissivity - 2.8 x 10^{-2} m^2/s
Storage - 3.6 x 10^{-4}

Multilayer confined aquifer (clayey-sand lithozone)
The top of this aquifer unit is marked by a lithological variation of the coarse layers: at the depth of about 100 m the gravel disappears and is substituted by sand and clayey sand. The bottom is conventionally taken at 300 m b.g.l. but, as already mentioned, there is not a particular marker at the transition between the lower unit of the shallow aquifer and the underlying fresh-water reservoir of the intermediate aquifer.

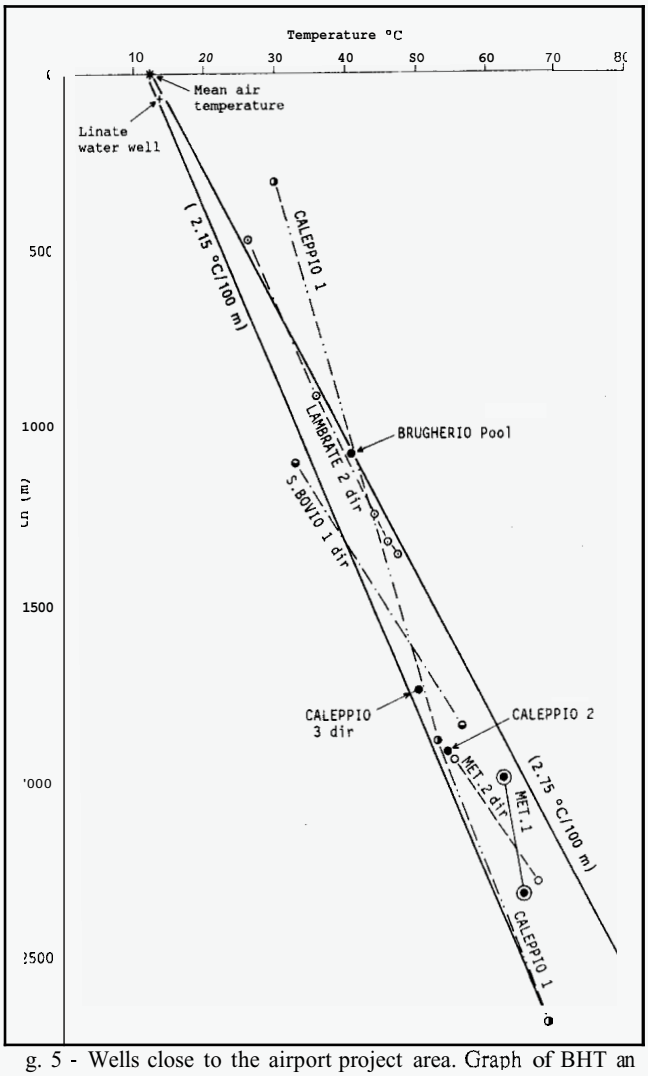
All the wells which penetrated the clayey-sand lithozone found several clean sand horizons for a thickness variable from 40 to 82 m. The individual horizons show an average thickness of 10 m each and are separated by thick intervals of clay and sandy clay. The whole forms a confined multilayer aquifer consisting of sandy layers partially interconnected. The flow direction is the same of the overlying confined aquifer (toward SSE) with hydraulic gradient of 1 x 10^{-3}.
The following average parameters were estimated for the study area:
Permeability - 1 x 10^{-4} m/s
Net pay - 40 m
Transmissivity - 4 x 10^{-3} m^2/s
Storage - 1 x 10^{-4}

4. TEMPERATURE

The sources of information for the reconstruction of the temperature dismbution at depth are represented by:
• values measured in pools by AGIP. These give a reliable value of the actual formation temperature
• values calculated from repeated measurements in hydrocarbon wells. These allow to obtain the bottom hole undisturbed temperature (BHT)
• values measured in hydrocarbon wells during the execution of production tests
• values of unstabilized temperatures at various depths
• temperature logs in the wells of the Metanopoli geothermal doublet and in the hydrocarbon well S.Bovio
• values measured during the production tests carried out in the shallow aquifer
• thermal logs carried out in shallow wells.

The values of pools and BHT stabilised temperatures, relevant to wells located close to the airport area, are plotted on the graph of Fig. 5. The average water temperature of shallow wells and the mean *air* temperature of the area are also plotted on the graph. Two main gradient lines include most of these values: a 2.15 °C/100 m and a 2.75 °C/100 m line. A remarkable scattering of values can be observed above the depth of 1400 m, and a linear interpolation between the deep measurements and the surface may lead to erroneous estimations, as far as the shallow and intermediate aquifers are concerned. For this reason, a detailed analysis was carried out in order to assess the probable temperature values of each aquifer. Values from conventional and high-resolution temperature logs were corrected by means of an analytical model accounting for the thermal conductivity variations which arise from the different dismbution of the main lithological types. The results are hereinafter described.

Deep Aauifer
The geothermal gradient is comprised between 2.35 and 2.55 °C/100 m in the area where the deep aquifer is present with favourable hydrogeologic characteristics (northernmost of the study area). The average water temperature of the aquifer, according to the depth of the producing interval, may be:
• 50.4°C from 1400 to 1700 m b.g.l.
• 52.9°C from 1500 to 1800 m b.g.l.
• 55.4°C from 1600 to 1900 m b.g.l.



g. 5 - Wells close to the airport project area. Graph of BHT an pool values (after AGIP) vs. depth

Intermediate aauifer

Due to the different depth of the pay intervals, the average provisional temperature values were differentiated between the northern and the southern sectors of the airport area, as follows:

- Northern sector: 35°C for the salt-water reservoir and 27°C for the fresh-water reservoir
- Southern sector: 39°C for the salt-water reservoir and 26°C for the fresh-water reservoir

Shallow aauifer

Water temperature values ranging from 13 to 14°C were measured in the aquifers of the gravel lithozone, at depths down to 100 m b.g.l.

In the lower part of the sequence (multilayer confined aquifer of the clayey sand lithozone) temperature values from 16 to 20°C, according to the depth of the producing interval, are likely to be encountered.

5. THERMAL AND HYDRODYNAMIC SIMULATIONS

The first target consisted of optimising the geothermal resources exploitation by one or two doublets, each combining a production and an injection well, drilled close to the airport facilities and runways. The well-to-well distance, at the top of the target reservoirs, must be spaced in order to avoid undue premature thermal breakthrough on producing wells, induced by injection into the reservoir of the heat depleted brine. It is generally accepted that thermal breakthrough time should not be less than 20 years, to secure an economic viability to geothermal exploitation. This was studied by means of thermal modelling of the displacement of the cold/hot water interface for given sets of geometric well locations and spacing, hydrothermal reservoir parameters, discharge-recharge rate and injected water temperature conditions.

The second target consisted of supplying provisional drawdown figures and checking the compatibility of the projected wells with those of the existing space heating doublet, drilled in the deep aquifer by AGIP on the nearby Metanopoli site.

The most favourable location and array of wells and doublets, besides to the relevant input parameters, were assessed on the basis of the hydrogeothermal picture. Well locations fall in the northern sector of the airport area as far as the deep aquifer and the fresh-water reservoir are concerned, in the southern sector for the salt-water reservoir. Several alternative configurations were analysed by means of mathematical simulations. A technico-economical analysis of the alternative exploitation scheme was then carried out. Itemised drilling/completion, surface investment and operation/maintenance costs were defined. Eventually, a recapitulative summary of costs vs. revenues allowed an estimate of the heat sales required to balance project expenditures.

Deep aquifer

A system consisting of one doublet and a multiple system consisting of two doublets were simulated. Mean yearly production/injection rates were fixed at 125 m^3/h from each doublet. Interference with the existing Metanopoli doublet was also taken into account. The depth of the wells varies from 1850 m for a vertical well to 2200 m for a deviated well. Well spacing at top reservoir is 1000 m. Production and injection temperature are respectively 53°C and 20°C. Thermal simulations show that there is no thermal breakthrough on the production wells after 30 years exploitation as a result of both aquifer thickness (150 m net pay) and well spacing. Hydrodynamic simulations show negligible interferences at Metanopoli when two doublets are operating at Linate airport and 3-4 m interference build up after 30 years when one single doublet is operating. Pressure drawdown and build-up in production and injection wells do not exceed 120 m after 30 years.

Intermediate aauifer - Salt-water reservoir

Systems consisting of one and two doublets were analysed. The well vertical depth is about 1500 m. As the bottom hole temperature is 39°C, a productiodinjection rate of 150 m^3/h was firstly considered, in order to improve the thermal yield supplied by the plant. Thermal simulations show that the temperature drawdown after 30 years is very low, less than 0.4°C. Hydrodynamic simulations show very strong pressure drawdown and build-up, on the order of 610 m after 30 years, without considering well losses and skin effects. This value was considered unacceptable for several technico-economical reasons and a productiodinjection rate of 75 m^3/h was then simulated. In this case the pressure drawdown and build-up would stand at 280-300 m.

Intermediate aauifer - Fresh-water reservoir

The advantage arising from this target is represented by a comparatively shallow depth of the wells, on the order of 850 m. A 27°C bottom hole temperature was estimated and a 15°C injection temperature was fixed, in order to increase the thermal yield. The simulations, addressing the hypotheses of one and two doublets, show thermal breakthrough from 0.6 to 1.6°C after 30 years. The pressure drawdown and build-up are very strong, from 900 m, with productiodinjection rate of 75 m^3/h, up to 1800 m, with 150 m^3/h.

6. PRELIMINARY STUDY OF AQUIFER HEAT STORAGE

Seasonal ambient temperature changes generate either excess or shortage of heat, which can be regulated via a suitable storage facility, i.e. a preferably shallow confined aquifer. Storage of sensible heat in the form of hot water poses the problem of the volume and cost of the storage facilities required to secure a technically feasible and economically viable exploitation scheme.

An aquifer storage scheme is contemplated at Linate as an alternative to either the existing heating/cooling system or a geothermal space heating doublet completed in the deep aquifer. The water (300 m^3/h;

25°C) rejected by the airport cooling system could be injected and stored during summer in one of the local shallow aquifers and pumped in winter to heat the airport terminal and related facilities.

Two alternative storage systems were analysed: a single well and a doublet system. The single well system allows injection and storage in the aquifer of the hot water rejected in summer by air conditioning and freezing, and pumping in winter time to supply heat to a heating network, possibly via heat pumps. The doublet system would combine a hot and a cold well to meet the needs of a heating/cooling application. The spacing of the wells with respect to temperature and pressure induced interferences is a critical point, in this case.

The simulations of this preliminary feasibility assessment were aimed at determining whether or not the storage issue is technically and economically compatible with user's heating/cooling requirements, in particular addressing the storage efficiency ratio with respect to inlet and outlet temperatures of a process based on heat-pump technology.

The low-cost option is represented by a single well completed in the water table aquifer (30-40 m well depth). Assuming a heating injection temperature of 20°C (formation temperature: 14°C), no atmospheric losses nor hydrodynamic displacement, the effective storage efficiency may be close to 70%. The correction induced by aquifer velocity (0.35 m/day) reduces the storage efficiency to 40%. A further reduction, due to the atmospheric heat losses through the upper unsaturated zone, must be considered: with a water table at 5 m from ground level the storage efficiency falls at 36%.

A doublet system completed in the water table aquifer would allow to maintain the efficiency at about 50%, by stabilising the displacement of the stored volume.

The semi-confined/confined aquifer, in the 60-70 m depth interval, was then considered. Investment and operation costs would be higher because of greater drilling/completion depths and higher pumping cost, the latter being a consequence of a comparatively low transmissivity (2×10^{-2} against 5×10^{-2} m^2/s in the upper water table aquifer). Nevertheless this aquifer is the most valuable target owing to a local aquifer velocity of 0.11 m/day: this would achieve a reasonable compromise as no atmospheric losses are present at the relevant depth and as a single well would be sufficient in order to maintain the storage efficiency at 61%, which is deemed satisfactory so far.

7. CONCLUSIONS

The main outcome of the hydrogeothermal study, of the thermal and hydrodynamic simulations and of the technico-economical analysis are the following:

- the fresh-water reservoir showed little geothermal interest (low temperature and productivity)
- the deep aquifer is the more reliable alternative, particularly regarding productiodinjection energy costs, owing to its dependable reservoir characteristics. The savings achieved on energy and injection well costs largely balance the reduced depth (drilling costs savings) sought from the intermediate salt-water aquifer option which is, in addition, penalising regarding its lower formation temperature
- a multiple system consisting of two doublets in the deep aquifer can be foreseen in order to meet the heat demand of the airport installations
- should the drilling of the first deep doublet meet comparatively favourable conditions within the intermediate aquifer, an alternative solution may be envisaged. This is represented by one doublet in the deep aquifer for space heating, and one doublet in the intermediate aquifer for runways de-icing and de-misting (the relevant heat demand can be satisfied with a comparatively low temperature drop and production rate)
- interseasonal storage of sensible heat in the shallow aquifer can be technically envisaged in the area of the Linate airport. The results of the preliminary feasibility study show that the semi-confined/confined target, at 60-70 m below ground level, appears as an acceptable cost/efficiency compromise, maintaining the storage efficiency close to 60-70%.

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