Chapter 2

Hydrogeological setting of the area

2.1 Geological setting

The study and knowledge of the geological formations of the underground metropolitan area of barcelona is not straightforward. Progressive urbanization of the city, strongly increased in last 30-40 years, has covered the soil with buildings, infrastructures and communication networks. As a result, existing rocky and sedimentary outcrops have disappeared. Because of this, it must be noted that the fact of consulting old geological maps (before 30-40s) has been priceless in many aspects.

Nowadays, it is possible to collect data from soil drilling with very different objectives (structural, geotechnical, hydrogeological and so on). Their reliability and shortage make them have a local relevance and a certain degree of uncertainty when it comes to the later geological interpretation task. Most of this drills are quite shallow so that their geological value is limited.

In comparison with the Llobregat delta, Besos delta was a relatively non-studied area until recent years in terms of geology. Despite this, some similarities between both formations have been noticed. Some of them are synthesized below.

The Besos delta is a fluvio-deltaic formation with important thicknesses (around 70 m. at some points) clearly related to the erosive and sedimentary activity of the Besos river (formation and erosion of the terraces), the changes in the sea level during the quaternary era and glaciations. These quaternary deposits are, in chronological order:

- Edaphic and superficial clays and silts
- Heteromerous sands
- Dark clayey silts
- Sands and gravels

So as to create a detailed numerical model of the Poble Nou neighborhood it was necessary to revise the geological data of the area. Former data provided the completion of a first rough approximation of the geology of the delta. This collection was used in the creation of the general model of the Barcelona plain.[9]

Despite this first approximation, the project required a more accurate model. In order to reach this desired level of detail, the initial conceptual model has been contrasted with all the data inferred from the geotechnical works carried out in the zone during last years, historical files of the city and the inventory made by the Water Agency.

A series of geological profiles enclosed in this project are the result of all the available information gathered and 160 boreholes buried in the area of interest. These profiles have been used in the geometrical definition of the model.

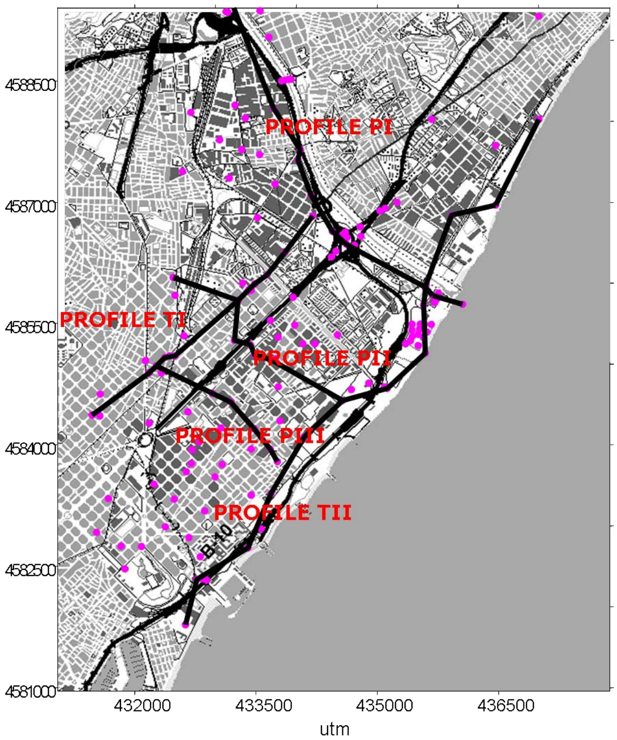

Figure 2.1: Distribution of boreholes and geological profiles[10]

The geological review offered here has been formulated from a wide documentation of the boreholes perforated in the Besos delta from the beginning of the 20th century. Reviewed documentation comprised UPC information, borehole data of different infrastructures, groundwater boreholes inventory collected by the ACA, etc. Hence, the primary materials that have been defined are, arranged by date:

Paleozoic Shales and granites

Tertiary Very compact Greeny clays of the Miocene-Pliocene

Quaternary Colluvial and deltaic deposits

- Upper sands and clays
- Organic sands and silts
- Lower sands and gravels

One of the main reasons of reviewing the geological data of the Poble Nou quarter has been the fact of defining with better accuracy the extension (lateral and depth) of the quaternary detrital materials, their relation with the colluvial materials and their contact with lower materials. Within the deltaic materials, a special effort has been made to size the extension of fine materials (clays, silts or black fine sands) since they are crucial when it comes to confine the different aquifer levels because of their low permeability.

These quaternary sediments as a whole are concentrated in the alluvial valley of the Besos river, forming a small delta in its mouth. The deltaic zone goes from the railway station in Glories square, Poble Nou, Sant Adria and Badalona.

In general, it can be accepted that these alluvial and deltaic quaternary formations are randomly distributed over a lithologically diverse base(granites, shales or clays) that can be considered as an impervious substratum. In the vicinity of Montcada, the substratum is constituted by shales from the Silurian age turning into granites in the so-called "Central del Besos". Substratum is essentially clayey from the pliocene age in Sant Adria. This pliocene socle is mainly composed of blued clays reaching thicknesses of 150 m. near the cost, with uppermost strong detrital levels and up to 20 m. thick conglomerates of the Pliocene.

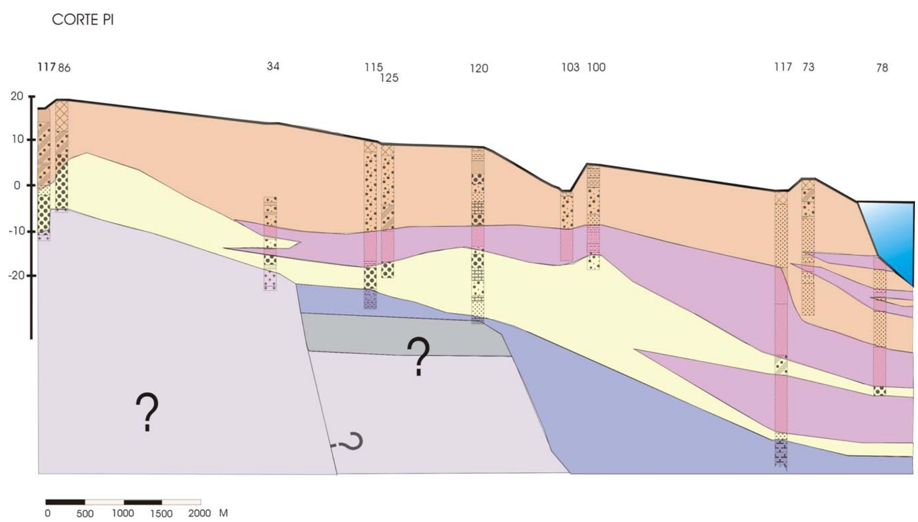

Figure 2.2: Geological profile parallel to the river(PI)[10]

A sand and gravel formation spans along the river course and all over its width. From Santa Coloma, black organic silts increasing in thickness in the sea direction penetrate this formation. These silted layer decreases its thickness towards the limits of the delta and it becomes sandier. These silts appear to be estuary facies(2.2).

There are many levels apparently with alluvial origin wedged between the oldest terraces and the colluvial deposits of the Barcelona plain(2.3). These type of deposits are essentially constituted by red clays and yellow sandy silts with limestone crusts and sandy and gravel deposits at the base. Over the clayey substratum of the pliocene in the deltaic coastal zone a level of coarse gravels(diameters up to 20 cm.) with coarse and fine sands of eolic origin, mainly towards the upper part, and some clayey intersections constitute the deep semi-confined aquifer of the delta.

The group is covered with the thick dark silty layer, of estuary formation, with a notorious organic matter content and clay and sand traces. The upper level is formed by deltaic gravels and sands clayey levels constituting the superficial aquifer. This level may contain clayey levels and soils at the top or it may be covered with filling materials supplied by the human being.

As a result of all these considerations, a number of modifications were made in the former geological model:

1. The uppermost silt layer has been replaced in most of the delta for anthropic fillings randomly overlaying it.

2. The superficial sandy complex or fluvial-deltaic origin is formed by sandy banks with disperse gravels and interspersions of clays. Its thickness ranges from 15 to 25 m.

3. The silty complex, of deltaic origin, is constituted by dark silts with plenty of organic matter and formation water. The complex changes laterally to very fine dark sands. This wedged complex has a maximum thickness of 30 m. near the coast, decreasing as it moves inland until it disappears. From now on, both upper and lower sandy complexes get linked as a single aquifer.

4. The lower detrital level is formed by layers of gravels, more or less cemented, alternating with sandy levels. Within this level, a second layer of black silts is noted, with a smaller lateral extension and wedge-shaped, focused in a thin trace parallel to the coast.

The materials of this complex are discordantly laid over the marls of the Pliocene in most of the delta, over the detrital pliocene materials of the occidental part of the Barcelona plain and over granites in its oriental part(Santa Coloma and Badalona).

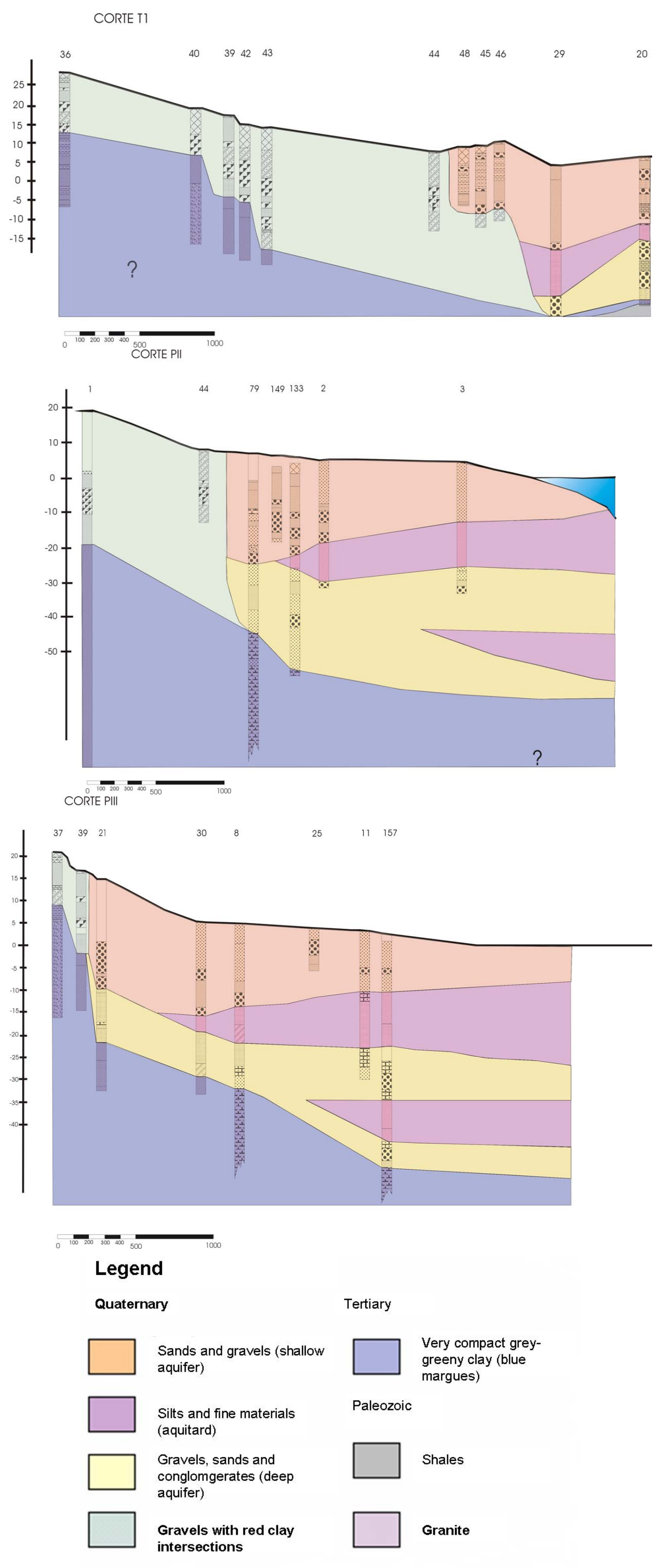

Figure 2.3: Several geological profiles[10]

2.2 Hydrogeological units

The geology of the Besos delta, typical from sedimentary deltaic areas, has a complex structure. First of all, the entities that form it do not have lateral continuity, so it is easy to find granularity changes. At last but not least, there are interspersion of clayey materials with permeable sands or gravels.

However, this geological complexity has a much easier hydrogeological consequence. From the hydrogeological point of view, we will only take into consideration the existence of two aquifers:

1. A superficial level composed by the upper detrital complex described above, where predominate sandy interconnected levels. This level behaves as an unconfined aquifer and the water table is quite close to the soil surface. As a result, it creates a lot of problems to urban infrastructures.

2. A confined level related to the lower detrital complex defined before. These level of the aquifer denotes important complexities as well, like very local silts interspersion in the coastal zone that have not been considered in the model due to its small scale. Thus, we only take into account the whole detrital model as a deep confined aquifer.

The intermediate silt level that separates both aquifers can be assumed as an aquitard, that is, a formation that allows very slow water flux between the two levels that it separates. Inland, when the intermediate silted wedge disappears, both upper and lower detrital complexes get together and hydraulically connected as a single aquifer.

It must be noted that embedded sand layer could appear in the silt layer randomly distributed. They could even form small confined aquifers. Because of their relatively small volume, their erratic distribution and the reduced possibility of renewing their water they have not been considered in the numerical model.

2.3 Hydraulic parameters

In the numerical model presented later, a number of different zones have been delimited according to the main geological formations. Each of their transmissivity values were estimated within a range[10] from the data inferred from hydraulic tests, estimations derived from specific capacities values and the calibration of consecutive numerical models.

The intensive groundwater abstraction rates in the second half of the 20th century kept the piezometry of the area quite low. From the 70s on, when most of the industrial activity ceased, the "water levels" started to increase until nowadays. This effect has been more intense in those areas where the pumping rates were higher, like in the Besos area. On the other hand, negative effects took place in the areas where the piezometric levels originally were near the soil surface. A remarkable example of this situation is the Poble Nou quarter, but the same problem is also affecting other low zones of the city.

In recent studies[3] a global hydrogeological balance has been defined and its main components quantified. The major inputs or recharges to the medium come from leakage from sewers and mains and direct infiltration. The most important outputs are groundwater abstractions in active wells and drainage from underground structures like the metro, underground parking lots, etc. Natural discharge of the aquifer takes place toward the sea, although in former years a severe process of seawater intrusion was affecting the aquifer as a result of intense pumping.

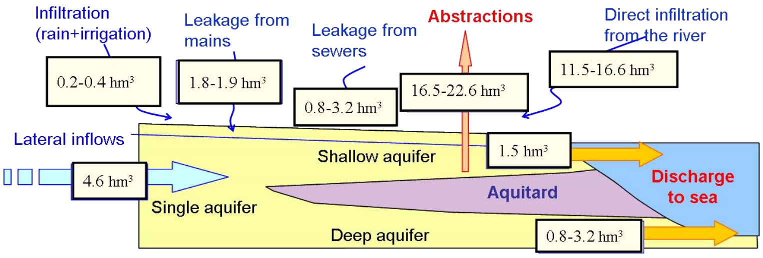

Figure 2.4: Hydrogeological balance of the Besos delta[3]

Taking a look at the piezometry, a series of deductions about the flux scheme of the delta can be made. The hydraulic gradient int the Delta is variable. Gradients of 0.4% can be found in the upper part of the delta while in the coast, it may be even lower than 0.1%. The piezometry of the Delta is influenced by the existing pumpings. Their goal is to prevent some elements from being affected by filtrations, water pressures, etc. This happens in infrastructures like the metro, parking lots and big buildings like industries or universities(Pompeu Fabra). As a result, some negative water table levels can be found in the delta, but they are much lower than in former years.

In the area of Santa Coloma, the river is not connected to the aquifer. The river transfers some water to the aquifer but they are not hydraulically connected. This phenomenon is called the shower-effect. In Sant Adria, the aquifer is also partially recharged by the river except from the final part, where it looks like the phenomenon reverses.

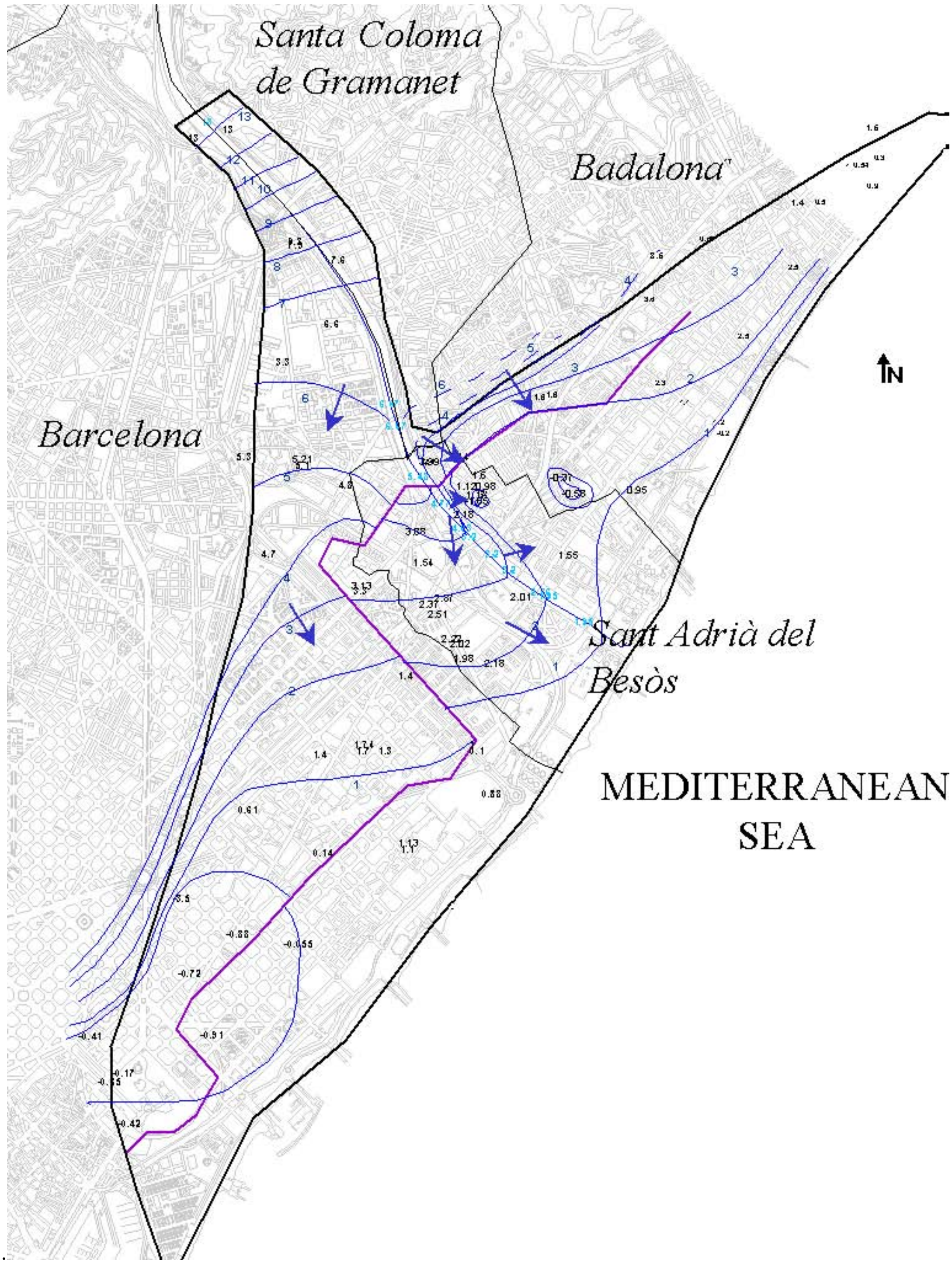

Figure 2.5: Piezometry of the Besos delta(2002)[10]

2.4 Temperature in the aquifer

So as to determine the temperature of the aquifer in the studied zone, a monitoring process of the temperature of several wells has been carried out. A series of vertical temperature and electrical conductivity profiles have been measured all along the depth so as to determine the thermal differences between the upper and lower levels. There are wells in which the existence of certain installations made it impossible to set the sensors.

The temperature in the upper levels remains between the 20.3°C of the Titan well and the 17°C of the Montsolis well. It is straightforward to conclude that in the upper part of the aquifer the temperature variations are mainly influenced by the atmosphere temperature. All the measures have been made between December and January. Because of this, we expect the temperatures to be higher in the rest of the year.

In general, the temperature of the atmosphere alters the temperature of the first meters of the soil. As we move down in the well, temperature fluctuations diminish until the thermal equilibrium with the soil is reached.

At depths of 20-30 m., these fluctuations are not noticeable and at greater depths, the temperature of the aquifer increases linearly as a result of the local geothermal gradient. An approximate value of this gradient is 3°C per each 100 m. depth.

Four vertical profiles in the Titan, Montsolis, Fabra and Coats and Wastewater treatment plant wells have been made. Length of these profiles has been determined by the depth of each well.

In those wells where pumping is often carried out, the vertical variations of temperature are minimal (Fabra and Coats, Montsolis wells). This happens because while water is abstracted from a well, a certain mixture with water from the well occurs. On the other hand, in those wells where pumping is not such an active process(Titan and wastewater treatment plant wells), marked vertical temperature variations can be measured. These relatively more important differences range from 0.7 to 1.1 °C between the water table and 15-20 m. depth respectively.

In wells situated in the UPF, the thermal difference is higher because of the greater depth of the wells. In general, temperatures measured in an aquifer are constants throughout the year. A sample of temperature fluctuations in some wells in Barcelona is depicted in figure 2.72.9.

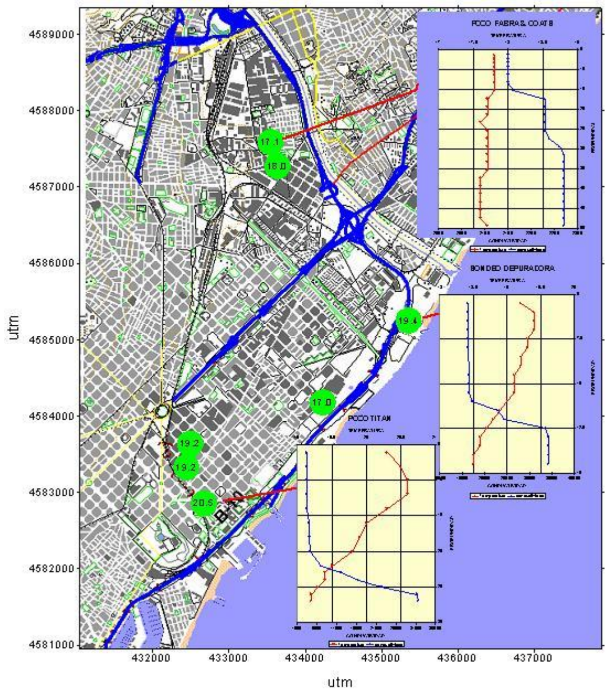

Figure 2.6: Temperature data collected in the field campaign between December 99- January 00[10]

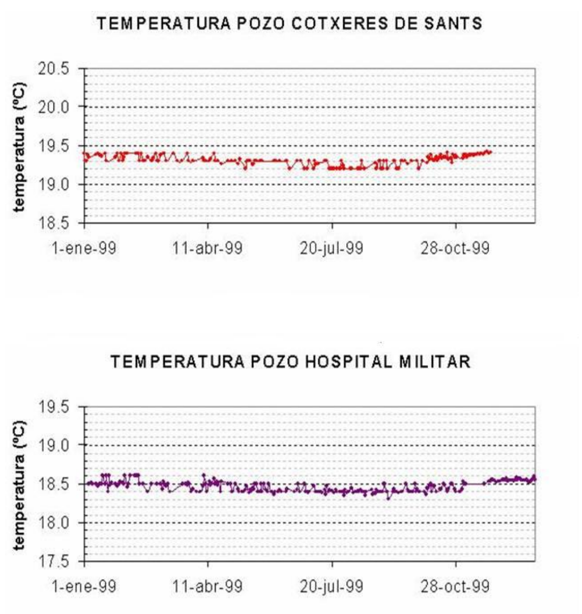

Figure 2.7: Evolution of the temperature in the wells in 1999

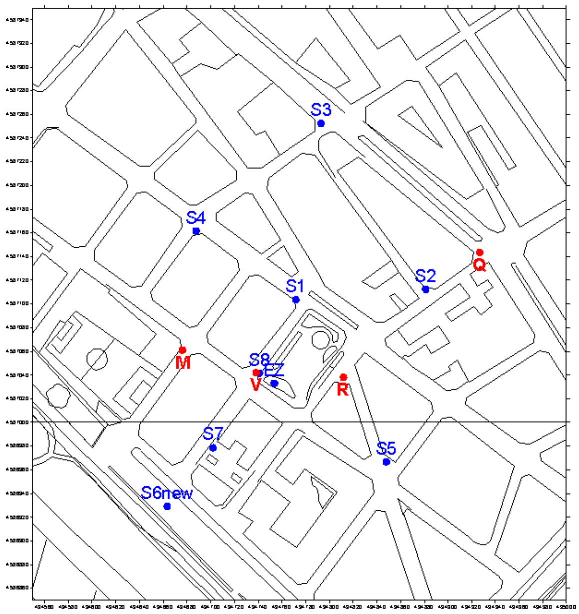

Figure 2.8: Sant Adria wells

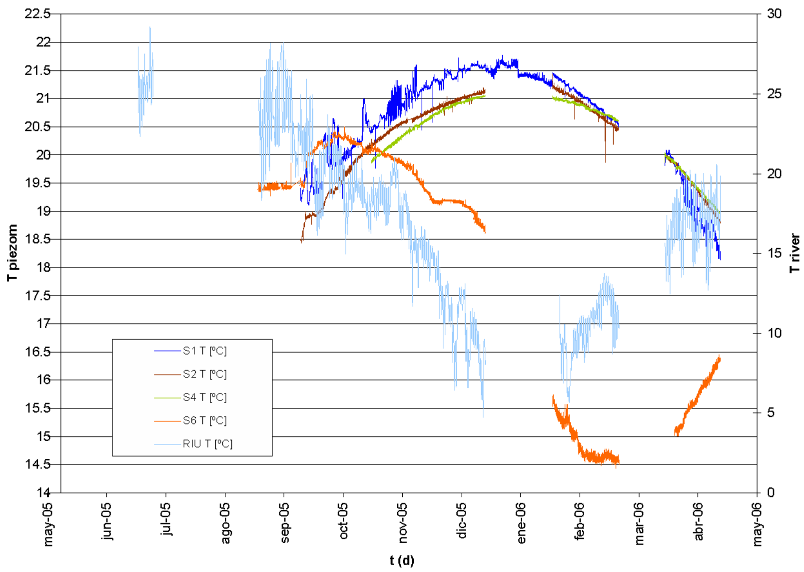

Figure 2.9: Evolution of the temperature in Sant Adria wells in 2005