EAGE

FIELD TRIP
Managed Aquifer Recharge at Llobregat Valley

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EAGE Field Trip

Managed Aquifer Recharge at Llobregat Valley

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Managed Aquifer Recharge at Llobregat Valley (NE Spain)

Field Trip Summary

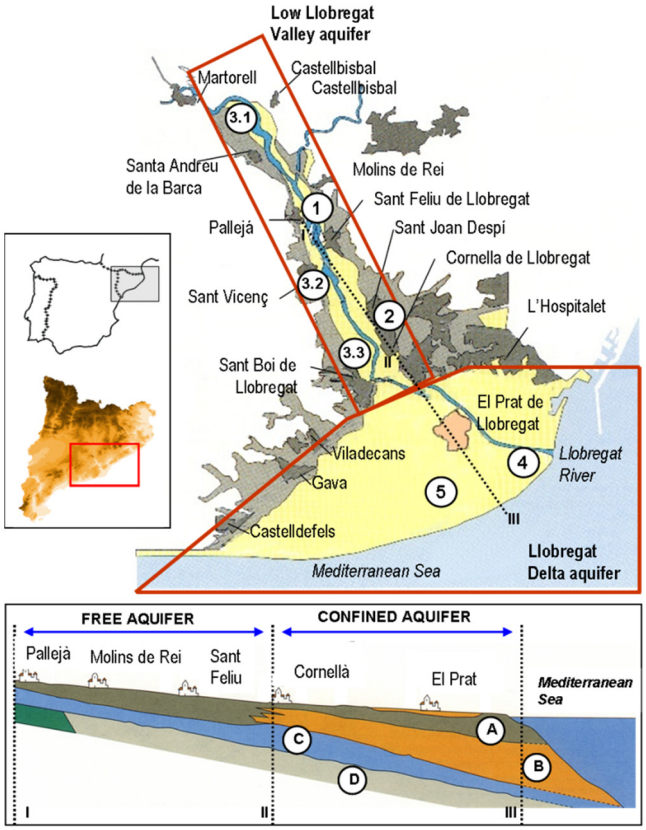
This field trip will demonstrate the different strategies developed for water supply to around 3 million of citizens leaving in Barcelona metropolitan area. Due to the Mediterranean climate, the natural water resource availability can sometimes be lower than the water demand in the area. This situation leads to the need to find alternative resources in order to ensure the potable water supply in the entire water network. The Llobregat Delta Aquifer has historically been a strategic water supply resource for the Barcelona metropolitan area. The use of river water combined with the exploitation of groundwater resources during dry periods has enabled the demographic and economic growth of the Barcelona area during the last sixty years. The aquifer overexploitation has entailed the decrease of groundwater level and the consequent seawater intrusion. The main consequences have been the salinization of several wells and the deterioration of the groundwater quality. For overturning this effect an artificial aquifer recharge system to improve the quality and quantity of water has been implemented using recharge wells and superficial infiltration ponds. Moreover, a hydraulic barrier against saltwater intrusion has been installed in the coast.

Within the field trip, some stops are planned for visit a water museum, an artificial aquifer recharge system, to have an overview of a waste water treatment plant and know a hydraulic barrier project against marine intrusion. The field trip will end in the Barça Camp Nou Stadium where some environmental and engineering geophysics studies are to be presented.

Locations and Themes

Hydrogeological background of the Llobregat Delta Valley

The total recharge area of the LLobregat Delta aquifer is of 110 km^2, with a maximum storage capacity of 114 hm^3. This aquifer is composed by Quaternary sedimentary materials coming from the erosion of the materials of the Llobregat River and its tributary rivers. These Quaternary materials are fitted in older materials, from Paleozoic to Pliocene. The Llobregat river lower valley and Delta are located in the Barcelona Metropolitan Area, they consists of about 30 km^2 of alluvial valley, up to 1 km wide, and 80 km^2 of delta. The Delta is formed by a sedimentary body of sands, gravels and clays ranging from Pliocene to Quaternary. In the low Llobregat Valley, the aquifer is unconfined and can be recharged by infiltration. From the beginig of the Delta to the sea, the aquifer bifurcates in an upper free aquifer (up to 15m beneath the surface) and a deep confined aquifer, this is called Main Aquifer and the maximum deep is between 55 and 70m with respect to the topography. Both aquifers are separated by an aquitard with increasing thickness reaching 40m to the sea. The Llobregat Delta Aquifers, in the proximity of Barcelona area, are an important water resource for urban, industrial and rural supply. Overexploitation in the 70's, and the proximity to sea, caused an important saline intrusion.



Overview of the Llobregat Delta aquifer. ***In the top****: location of the main recharge actions. Sites visited in this field trip: (2) Cornellà, Aquifer Storage and Recovery wells (ASR); (3.2) Sant Vicenç dels Horts infiltration pond and (4) hydraulic barrier.* ***Bottom:*** *hydrogeological context. (A) Upper aquifer (sand and gravel); (B) Aquitard (clay and silt); (C) Main aquifer (confined) (sand and gravel); (D) basement previous to quaternary. Source: Modified from Armenter 2008.*

Cornellà - Water museum and recharge well

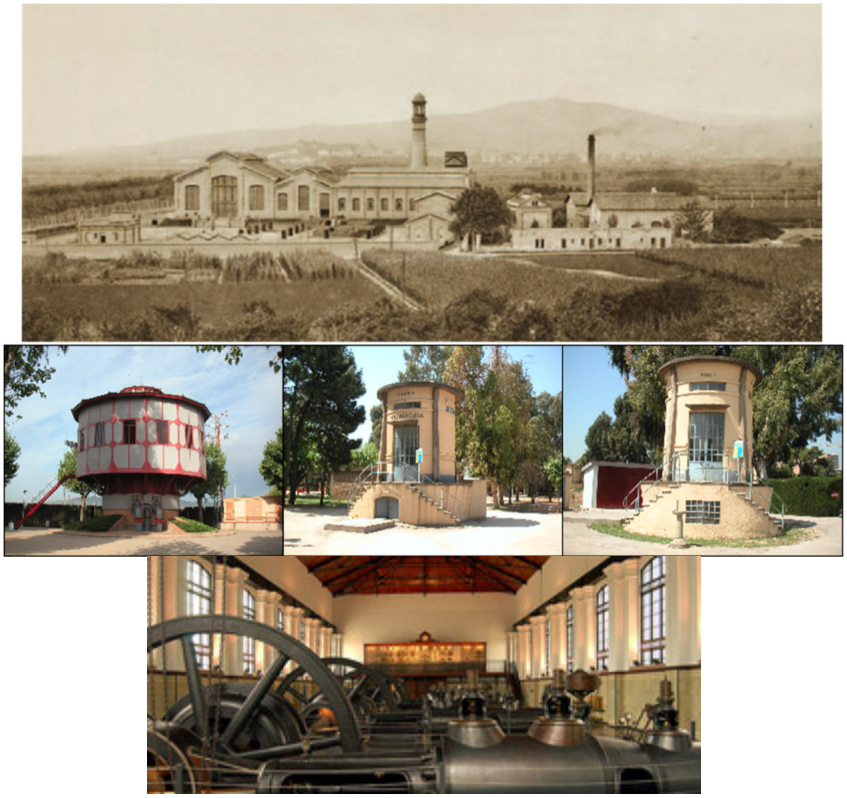
In this site, the history of Barcelona water supply and the history about the exploitation of Llobregat aquifers will be exposed.

Groundwater has constituted throughout the years a strategic resource for Barcelona and his metropolitan area, being a fundamental piece for their demographic, industrial and economic development.

In last sixty years, superficial water of the Llobregat and Ter rivers have allowed to preserve mostly of the aquifers and the use of its water to complement the demand in periods of hydrographic deficit or in episodes of deficient quality of the rivers water. In order to ensure the sustainable exploitation of the aquifers it has been essential to protect aquifer water avoiding his deterioration and overexploitation, enhancing water supplies by means of artificial recharge operations and adapting the water treatment systems.

The role of the underground water supply to Barcelona will be explained in the visit to Central Cornellà, a modernist industrial architecture building conceived by the architect Josep Amargós i Samaranch and constructed in 1900. From this time it shelters the first centralized facilities to supply Barcelona city and its metropolitan area with drinkable water from the Llobregat river aquifers. Nowadays it continues being the head plant of elevation of the drinkable water proceeding from the water treatment station of San Joan Despí and shares facilities with the Museu de les Aigues, a contemporary museum devoted to water, its properties and the history of water supply. A guided visit to the museum permanent exhibition will be conducted in this field trip.

The visit will end in the well number 1 of Cornellà, contemporary of the building and still in service. From this site, the recharge system in depth of the aquifers by means of wells will be explained.



Related links

www.museudelesaigues.com

https://dessin-project.eu/?page_id=16 *European water DESSIN project for demonstration and promotion of innovative solutions for water scarcity and water quality related challenges.*

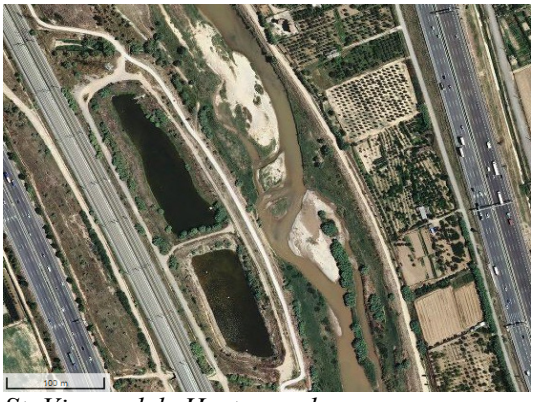
Sant Vicenç Dels Horts - Artificial aquifer recharge site: geophysical, hydrological and geochemical surveys

One of the most common methods of artificial water recharge is the use of superficial infiltration ponds. It requires excavation of permeable terrain close to the water source. These systems can also have a decantation pond to improve water quality through deposition of suspended solids. The artificial aquifer recharge system located in Sant Vicenç dels Horts is one of the pioneer systems in Spain. It was built in 2007 and started functioning between 2008 and 2009, under the management of the Catalan Water Agency (ACA) Public hydraulic Administration. The system recharges the low Llobregat Valley aquifer and was designed to receive water from the Llobregat River in the floodplain on the right bank or reclaimed water from El Prat de Llobregat Waste Water Treatment Plant (WWTP) in case of drought. St. Vicenç dels Horts pond includes a decantation pond of 4000m^2 followed by an infiltration pond of 5600m^2. The estimated annual recharge in this site is about 1.6 hm^3/y. With the aim to improve the efficiency of the system, several infiltration tests have been done to identify the areas presenting higher infiltration rates. As a result of these tests the average infiltration rate was 1m^3/m^2/d.

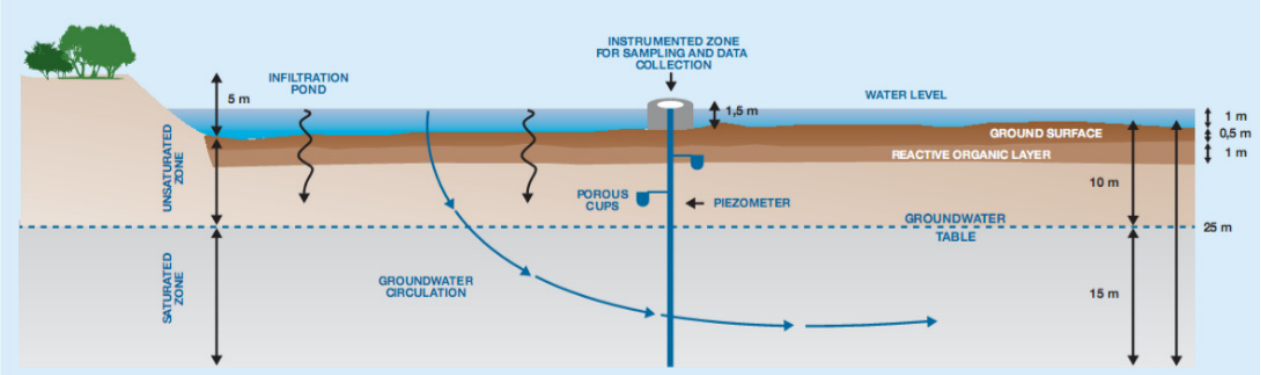
Sant Vicenç dels Horts pond has been used as pilot test site for R&D projects (LIFE+ENSAT) aiming at characterizing biologic, chemical and physical processes occurring both in the unsaturated and saturated zones during aquifer recharge. The pond has been equipped with a dense monitoring net of piezometers to control the water table (outside and inside of the pond) and groundwater quality. Moreover, the unsaturated zone has also been instrumented with tensiometers, hydraulic potential sensors, humidity sensors and porous cups.

Geophysical studies conducted in the area applying the ERT (Electrical Resistivity Tomography) technique have been useful to evaluate the relation between the electrical resistivity and the hydraulic parameters besides to monitor the non-saturated to saturated soil process after the beginning of the infiltration.

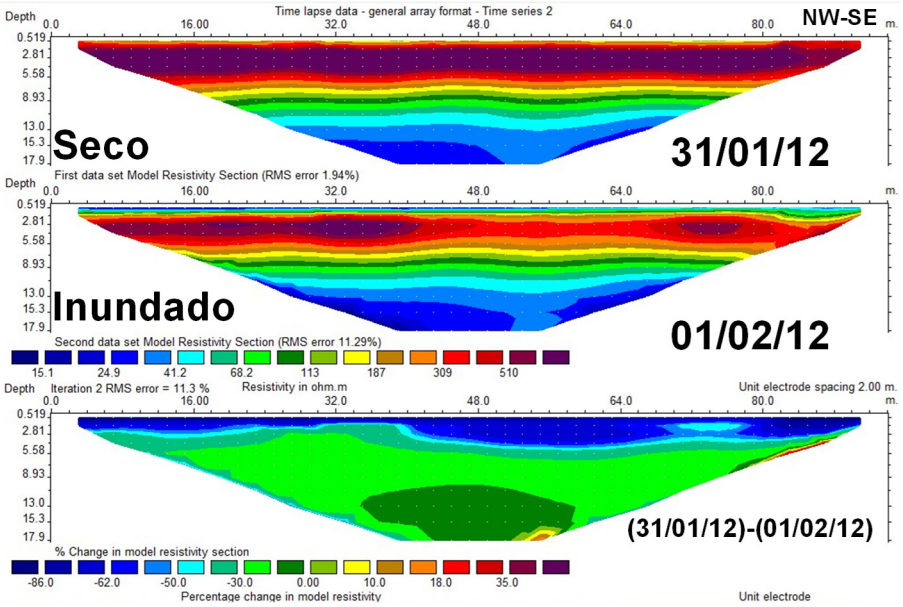
https://www.youtube.com/watch?v=O95IG_snI6E (ENSAT project)



Decantation and infiltration St. Vicenç dels Horts ponds.



Scheme of the ENSAT Project.



Geoelectrical sections. Up: dry pond. Center: inundated pond. Down: porcentual variation of electrical resistivity between the dry and flooded models (Sendrós, 2016).

El Prat de Llobregat - Waste water treatment plant and hydraulic barrier system

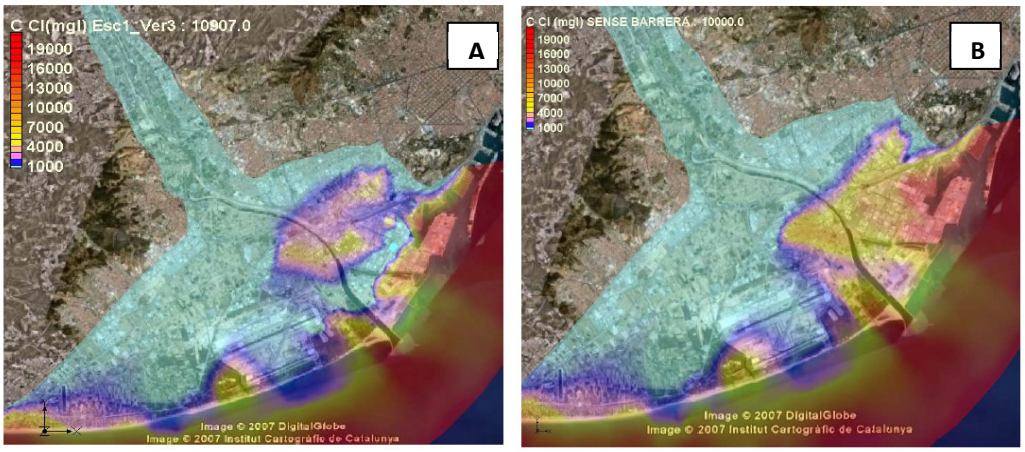
In this stop, participants will approach a viewing-point in the natural Parc del Delta de Llobregat to have a panoramic view of the Waste Water Traitment Plant (WWTP), the river and some injection wells. In this site, a presentation of the treatment plan, the hydraulic barrier project and the geophysical studies performed to support the construction and monitoring processes will be done.

The WWTP is one of the largest in Europe, traits wastewater from 2 Mhab and 100 Mm3/y. It is equipped with a conventional tertiary treatment so, aafter a biological treatment with removal nutrients in addition to ultrafiltration and reverse osmosis processes, reclaimed water can be injected into the aquifer through a hydraulic barrier as a corrective measure to prevent the advance of the seawater intrusion in the main Llobregat delta aquifer.

WWTP El Prat	Capacity (m^3/day)	Treated flow (Mm^3/day)
	420.000	96,3
USES: Agriculture, Recharge Ponds, Hydraulique barrier, River, Wetlands, Urban irrigation		

Viewing point in the Parc Natural del Delta de Llobregat, picture of the WWTP and table with related information.

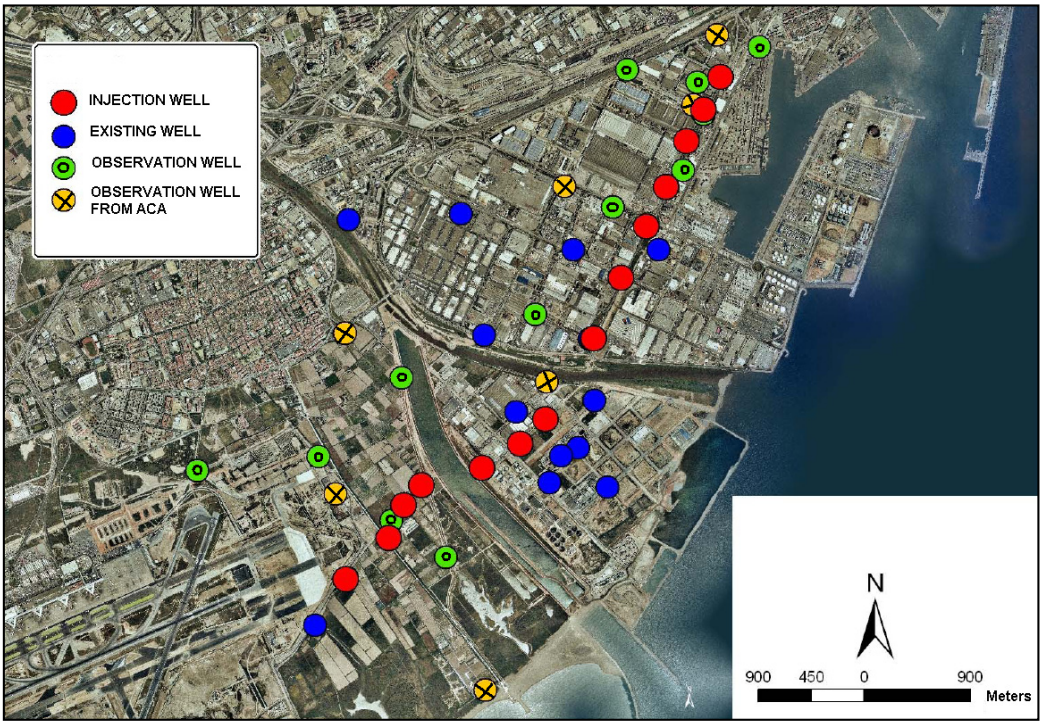
Nowadays seawater intrusion is affecting a third of the total surface of the Llobregat Delta. The prediction based on a numerical model developed by UPC (Technical University of Catalonia, Barcelona) with VisualTransin code foresees that half of the surface of the Delta will be saline in 30 years if no counter measures are undertaken (Vázquez-Suñé *et al*., 2006).



Forecast of chloride concentration in the Llobregat Delta aquifer for the year 2036. (A) With hydraulic barrier (B) Without hydraulic barrier nor infiltration ponds. Source: Ortuño, 2009.

The monitoring of water quality and quantity has been carried out with a control net consisting on existing piezometers and wells, as well as new piezometers that were constructed in the framework of the barrier project. There are 51 control points, 17 of them have been constructed with the purpose to monitor the hydraulic barrier. Wells are equipped with flow meters, as well as level, temperature and conductivity sensors. Water distribution tank is continuously monitored (conductivity, ammonium,

turbidity and pH). There are sampling campaigns each two weeks to analyze physic-chemical composition in piezometers (BOD, QOD, total phosphorus, total nitrogen, chloride, nitrate and TOC). Global elements and metals are analyzed each two months. Bacteriological controls (total coliforms, E. Coli and nematodes) are carried out each two weeks in the remotest injection wells from the distribution tank, where arrival time is about 3 hours from the treatment.



Monitoring network in the Llobregat hydraulic barrier. There are 14 injection wells, 17 piezometers equipped with temperature and electrical conductivity remote sensors. 7 previously existing piezometers and 12 industrial wells are also located. Source: ACA, 2009.

Several geophysical well logging surveys were performed in the different phases of the hydraulic barrier. Before the injection in the wells, the following measurements were implemented: recordings with a sonic sonde to verify the well construction, detecting the bentonite seal and the areas in which cement was not uniformly present behind the casing, measurements of Gamma Natural radiation to characterise the lithology and electrical conductivity and temperature of the water and electrical conductivity of the formation as a baseline. Later, during the working period of the hydraulic barrier, several monitoring well logging surveys were performed after water injection procedures for obtaining electrical conductivity and temperature of the water and gamma radiation of the formation. The parameters were useful to constrain the numerical models and to help the hydrogeological monitoring operations.

Well logging surveys in three piezometers of the El Prat de Llobregat Hydraulic barrier.

The hydraulic barrier has a protocol of operability and the injection rate largely depends on the level of the aquifer. In consequence, the activity of the barrier depends indirectly on droughts or periods of scarcity of water resources.

Related links

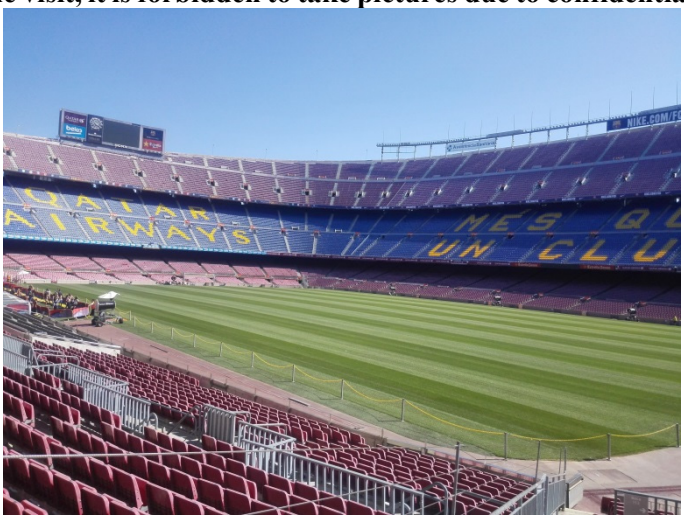
http://perfil.amb.cat/web/emma/aigua/sanejament/depuradores/depuradora_llobregat

"Camp Nou" Stadium – Environmental and engineering geophysics developments

The visit of this site is focused in two parts:

1. Grass and water irrigation engineering on the Camp Nou. This visit will be guided by a representative technical staff of the installation. Participants will visit the well system, the waste water treatment plant and know the engineering processes for the irrigation, temperature control and sunshine of the grass throughout the year.

During this part of the visit, it is forbidden to take pictures due to confidentiality and sensitivity reasons.



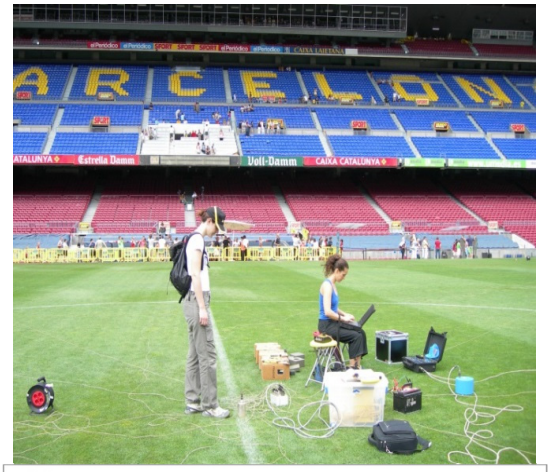
Barça Camp Nou Stadium.

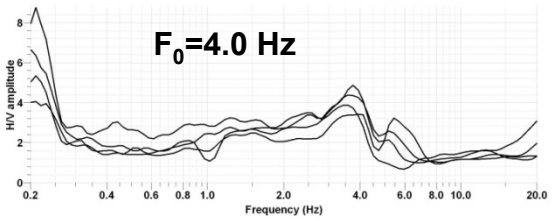
Related links

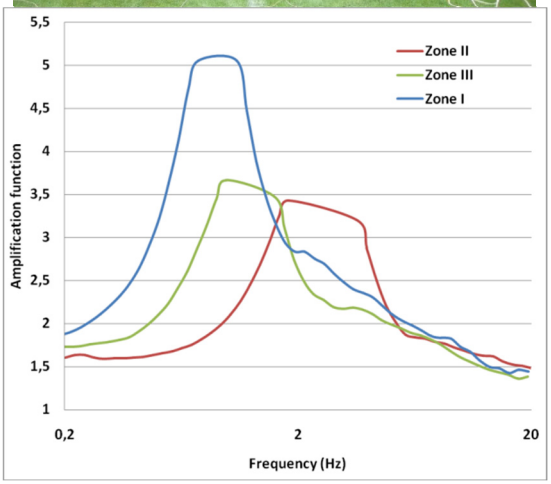
www.fcbarcelona.cat

2. Geophysics in the Camp Nou: a contribution to the local seismic hazard studies in Barcelona. Participants will have access to the football field and to the bleachers. From there, it will be presented a geophysical survey performed in the Camp Nou in the framework of the SISNEPI project (CGL2007-63576) for a seismic microzonation study to characterize soil effects in different Barcelona city areas.

The survey consisted in the application of passive seismic techniques to characterize the soil physical characteristics such as shear wave velocity profile and soil fundamental frequency. The correlation between geophysical and geological data provided useful information for the numerical simulation of seismic soil response and site effects characterization in this place.







Top: Pictures during the geophysical survey in the Camp Nou Stadium. Bottom: H/V seismic noise spectral ratio and amplification function for the three zones identified in the seismic microzonation studies performed in Barcelona city.

References

ACA (Catalan Water Agency) [2009] Acord de 8 de novembre de 2001, del Consell d'Administració de l'Agència Catalana de l'Aigua, pel qual s'aprova la Proposta d'acord per la qual s'estableix el règim d'explotació dels aqüífers de la Vall Baixa i el delta del Llobregat, la cubeta de Sant Andreu i la cubeta d'Abrera. *DOGC*, **3667**, 11818. http://www.gencat.cat/diari/3667/02168069.htm (Accessed 26 May 2010).

Armenter, J.L. [2008] Artificial recharging of the aquifers in the joint management of the resources in the delta of the river Llobregat. *Houille blanche-revue internationale de l' eau,* **6**, 63-69.

Ortuño, F., Niñerola, J.M., Armenter, F., and Molinero, J. [2009] La barrera hidráulica contra la intrusión marina y la recarga artificial en el acuífero del Llobregat (Barcelona,España). *Boletín Geológico y Minero*, **120**(2), 235-250. ISSN: 0366-0176.

Sendrós, A. [2016] *Using geophysical techniques in planning and manegement of groundwater resources. Application in Mediterranean aquifers*. PhD Thesis, University of Barcelona. Spain, 240.

Vázquez-Suñé, E., Abarca, J., Carrera, B., Capino, D., Gámez, M., Pool, T. Simó, F. Batlle, J.M. Niñerola, X. Ibáñez [2006] Groundwater modelling as a tool for the European Water Framework Directive (WFD) application: The Llobregat case. *Physics and Chemistry of the Earth*, **31**, 1015-1029.

SCHEDULE

- 8:30 - 9:45

From Barcelona to Cornellà.

-9:45 - 11:15

Cornellà, visit to the water museum and a recharge well with historical and geological explanations.

- 11:15 - 11:35

From Cornellà to Sant Vicenç dels Horts.

- 11:35 - 13:30

Sant Vicenç dels Horts, visit to the artificial aquifer recharge system and presentation of the different geological, hydrological and geophysical projects.

-14:00 - 15:00

Lunch break at Sant Vicenç dels Horts. Restaurant “Las Palmeras”.

-15:00 - 15:30

From Sant Vicenç dels Horts to El Prat de Llobregat.

-15:30 - 16:30

Panoramic view of the water waste treatment plant from Parc Natural del Delta de Llobregat with explanations and hydraulic barrier against saline intrusion project presentation.

-16:30 - 17:00

Back in Barcelona, from El Prat de Llobregat to the Camp Nou.

-17:00 - 18:00

Environmental and engineering geophysics on the Camp Nou Stadium.

-18:00

End of the Field Trip. Participants have the possibility to remain in the Camp Nou installations for shopping, and/or to visit the Barça museum (optional).