



## INFORME INTERMEDIO DE PROYECTOS COORDINADOS DE I+D+i

### A. Datos de coordinación

**Nota:** Relacione los subproyectos que participan en el proyecto coordinado

<b>Proyecto coordinador (1)</b>	<b>Referencia de proyecto: CGL2013-48869-C2-1-R</b>
Investigador Principal 1	Jesús Carrera Ramirez
Investigador Principal 2*	Enric Vazquez Suñé
Entidad	CSIC
Centro	Instituto de Diagnóstico Ambiental y Estudios del Agua
<b>Subproyecto (2)</b>	<b>Referencia de proyecto: CGL2013-48869-C2-2-R</b>
Investigador Principal 1	Maarten Saaltink
Investigador Principal 2*	Linda Luquot
Entidad	UPC
Centro	Departamento de Ing. Terreno Cartográfica y Geofísica

**Nota:** Cree tantas tablas como subproyectos formen parte de proyecto coordinado.

\* Rellenar si procede.

### B. Datos del subproyecto

**Relacione los datos actuales del subproyecto.** En caso de que haya alguna modificación, indíquelo en la casilla B2

<b>B1. Datos del proyecto</b>	
Referencia proyecto	<b>CGL2013-48869-C2-1-R</b>
Título	Mezcla y dispersión en el transporte de energía y solutos
Investigador Principal 1	Jesus Carrera
Investigador Principal 2*	Enric Vazquez
Entidad	CSIC
Centro	Instituto de Diagnóstico Ambiental y Estudios del Agua
Fecha de inicio	01/01/2014
Fecha final	31/12/2016
Duración	3 años
Total concedido	153.670€

\* Rellenar si procede.

### C. Personal activo en el subproyecto

Tiene que relacionar la situación de **todo** el personal de las entidades participantes que haya prestado servicio en el proyecto en el periodo que se justifica, o que no haya sido declarado anteriormente, y cuyos costes (dietas, desplazamientos, etc.) se imputen al mismo.

#### C1. Equipo de investigación

##### *Incluido en la solicitud original*

	Nombre	NIF/NIE	Función en el proyecto		Fecha de baja	Observaciones
1	Jesus Carrera	50287474K	Co-IP			



	Ramirez					
1	Enric Vazquez Suñe	37.329.227-C	Co-IP			
2	Marco Dentz	X04998364-G	Equipo investigador			

**No incluido en la solicitud original**

	Nombre	NIF/NIE	Función en el proyecto	Fecha de alta	Fecha de baja	Observaciones
1						
2						

**C2. Equipo de Trabajo**

	Nombre	NIF/NIE	Función en el proyecto	Fecha de alta	Fecha de baja	Observaciones
1	Juan Hidalgo	30.815.696-C	WP 1			
2	Jean Raynald		WP 1, 5			
3	Tanguy Le LeBorgne		WP 1, 5			
4	Joaquim Soler	47871333F	WP1 y 2, 5			
5	Sheila Fernández	44489262V	WP 2, 3, 5			
6	Berta Gómez	45853320Z	WP 2			
7	Carlos Casanova		WP 3, 5			
8	Pilar Queralt Capdevila		5			
9	Valentí Rodellas		5			
10	Alex Marcuello		5			
11	Fabian Bellmunt	52.798.335-H	5			
12	Harold Auradou		5			
13	Alexis Shakas		5			
14	John Selker		5			
15	Frank Selker		5			
16	Domitila Violeta Velasco	75955849M	6			
17	Alejandro Serrano	38826866-Z	6			

**Nota:** Cree tantas filas como necesite.

**D. Progreso y resultados del proyecto coordinado**

<b>D1. Desarrollo de los objetivos planteados en el proyecto coordinado (a rellenar por el coordinador)</b>		
<p>Describa los objetivos del proyecto coordinado y el grado de cumplimiento de los mismos (<b>porcentaje estimado respecto al objetivo planteado</b> señalando la participación de los subproyectos en su desarrollo). <b>Extensión máxima 3 páginas</b></p>		
Objective	Progress	Involved subprojects
Obj. 1: Improve the formulation of the	Progress as planned. We have advanced on the quantification of mixing in variable density flow through	CSIC



transport equation so as to reproduce not only the advection and dispersion processes, but also mixing.	heterogeneous media through collaboration with Politecnico de Milano (not planned originally). We have also advanced on multicontinuum model for transport, though not in variable density flow. Completed (40%)	
Obj. 2: Develop a code that includes this formulation and that permits to demonstrate that it is applicable to real phenomena	The objective has changed substantially, because we have abandoned development of PROOST. Instead, code developments are made on KRATOS, a computing platform developed by CIMNE (Barcelona, Spain) and on existing CSIC and UPC codes. Still, we did implement MRMT and reactive transport into PROOST (M2.1 and M2.2). Completed (70%)	CSIC, UPC
Obj. 3: Improve the understanding of geochemical processes in the seawater freshwater mixing zone by means of modelling, and laboratory and field experiments.	The scope of this objective has increased significantly through the high level of international attention the project has received (see section E.6) The regional groundwater transport model has been updated (M3.1) Density dependent flow model of the salt water intrusion wedge at the site is under construction (M3.2) Five three well nests and three single wells have been built and instrumented (the proposal included only 4 wells, see Section E for details). ERT tests have been performed (M5.1). Preliminary hydraulic tests have been performed (M5.2) and tracer tests are planned for November (M5.3). Laboratory experiments are under planning and preparation (M4.1 through M4.4). In addition, a large number of Optical Fiber tests, that were not planned originally have been performed. Completed (50%)	UPC, CSIC
Obj. 4: Define a procedure for calculating discharge flows of fresh water and nutrients from coastal aquifers to the sea	Progress as planned. We have made the first sampling campaign for nutrients and Ra isotopes (M5.4)  Completed (20%)	UPC
Obj. 5: Define a more accurate method for calculating the heat dissipated by wells in shallow geothermal low enthalpy systems	The objective has changed substantially, because instead of the classical thermal response tests, we are proposing to change to "Optical Fiber heating tests", which can easily provide a highly resolved (in space) picture of heat properties in the aquifer. This has caused some delay. Preliminary tests were performed in June (M5.7). A second test campaign is planned in September. Interpretation (M3.4) is pending. Completed (40%)	CSIC, UPC
Obj. 6: Implement all the above in a database coupled to a GIS to facilitate industrial exploitation in specific	Progress as planned. We incorporated sedimentological data from the boreholes into the GIS.	CSIC, UPC



cases.	Completed (40%)	
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**Nota:** Cree tantas filas como necesite

**D2. Actividades realizadas relacionadas con la coordinación del proyecto (a rellenar por el coordinador)**

Describa las **actividades de coordinación** realizadas para alcanzar los objetivos planteados en el proyecto. Indique para cada actividad los subproyectos implicados. **Extensión máxima 1 página.**

Coordination has been performed through the following set of activities:

- 1) Periodic consortium meetings. We meet monthly to discuss project progress;
- 2) We have held specific meetings for:
  - 2.1) Siting of the wells
  - 2.2) design of the wells
  - 2.3) Optical Fiber workshops
- 3) Weekly seminars organized by the GHS-CSIC-UPC and attended by GHS members and, when appropriate, announced to broader audiences (see F.4);
- 4) One "Quo vadis" meeting, organized by the GHS-CSIC-UPC and attended by all GHS members.
- 5) A workshop was organized by CNRS-Rennes in July, 2015. A number of MEDISTRAES participants (see E.5). We took advantage of this workshop to coordinate activities with the Rennes group and with the Oregon University group.

The GHS Website is being reworked, which has hindered the preparation of a ME DISTRAES to allow easy and fast access to public documents and to communicate meetings, workshops, and public deliverables, among others, to the interested public. In the mean time we are using a google drive site for documents sharing.

**Nota:** Los apartados D1. y D2. deben ser rellenados por el proyecto que coordina, pero debe **incluirse** también en los informes de los subproyectos que forman parte del proyecto coordinado.

**E. Progreso y resultados del subproyecto**

**E1. Actividades realizadas y resultados alcanzados por el subproyecto para la consecución de los objetivos del proyecto coordinado**

Work Package (WP)	Participants
WP1. Mathematical methods We have advanced on the quantification of mixing in variable density flow through heterogeneous media through collaboration with Politecnico de Milano. We have also advanced on multicontinuum model for transport, though not in variable density flow.	Marco Dentz, <b>Jesús Carrera</b> , Juan Hidalgo, Jean Raynald de Dreuzy, Tanguy Leborgne, Maarten Saaltink, Joaquim Soler.
WP2. Development of numerical codes We added to Proost, a code for simulating coupled processes, the capacity to use the method of MRMT (Multi Rate Mass Transfer). Moreover, we developed a new method for calculating reactive transport (WMA) that has been implemented into Proost. Currently, we are testing the combination of reactive transport and MRMT. As the development of Proost will not be continued, we decided to start to work with another platform, Kratos, a framework for building multi-disciplinary finite element codes. We created a code for modeling transport of solutes and heat with density flow, which is now tested. We have started the development of a code for parameter estimation from Electric Resistivity Tomography data.	<b>Jesús Carrera</b> , <b>Maarten Saaltink</b> , Sheila Fernandez, Joaquim Soler. Berta Gómez.
WP 3: Modelling Based on previous numerical model of the Catalan water Agency, an updated numerical model of the Argenton aquifer was carried out for the period 2006-2013. This model should give us the boundary conditions to construct a transport	<b>Maarten Saaltink</b> , <b>Jesús Carrera</b> , Sheila Fernandez,



<p>model of the study site. However, results of this model indicate that the conceptual model is not well defined as the numerical is not able to simulate the years with high recharge. So, the regional model has been discarded as input data.</p>	<p>Jordi Garcia-Orellana, Carlos Casanova, Albert Folch, Laura del Val</p>
<p><b>WP 4: Laboratory experiments</b>  The columns setup has been designed to perform the different laboratory experiments proposed in the project. Nevertheless, before starting the laboratory experiments, we focus the research on the characterization of the Argentona field lithology and mineral composition using the cores obtained during the drilling. Granulometry analysis and X-ray diffraction measurements have been done to determine the mineral compositions and the different geological units (sand, clays, gravel, and granitic saprolite).</p>	<p><b>Linda Luquot</b>, Laura Martínez, Joaquim Soler, Laura del Val</p>
<p><b>WP 5: Field experiments</b>  Previously to the set up of the experimental area of the project in Argentona ephemeral stream basin (Figure 1), sampling and measurement of chemical compounds were carried out in two ACA and a hand-made piezometers in the first months of the project. Results of this campaign, mainly focused on the behavior of Ra isotopes in the subterranean aquifer, are compiled in an article that is in preparation.</p> <p>The experimental area of the MEDISTRAES project is located in a small section of the lower part of the Argentona stream. It has been equipped with 15 shallow piezometers and a pumping well. The piezometers are distributed along two main axes, a first one perpendicular to the coast and a second one parallel to the coasts (Figure 2). They have been equipped with the following instrumentation:</p> <ul style="list-style-type: none"> <li>- Vertical Electric Resistivity Tomography (VERT) downhole electrodes: The deepest piezometers, those close to the sea and the pumping well, were equipped with downhole electrodes in order to perform Vertical Electric Resistivity Tomography.</li> <li>- Fiber optics Distributed Temperature Sensing cable: Two single steel armoured fibre optic sensing cables (BRUsens cable Temperature, Brugg Kabel AG, Switzerland) were installed in all boreholes, resulting in two lines of around 600m length each.</li> <li>- Continues monitoring sensors: Groundwater levels and temperature (Mini-divers, Schlumberger) are being continuously monitored every 15 minutes in all piezometers, while electro conductivity (LTC Levellogger Junior, Solinst, Canada) is also being monitored in 5 of the 16 boreholes.</li> </ul> <p>Short pumping test have been carried out in all boreholes, which can give information of hydraulic properties (transmissivity) near each borehole, as well as the hydraulic connections between them.</p> <p>Sedimentological log testing in the 15 boreholes. Gamma logs have been recorded to verify the depths of the boreholes, validate the information derived from the borehole cores, and confirm the position of the VERT electrodes along the borehole casing.</p> <p>Sedimentological cross section panels defining the detailed 3D sedimentological architecture of the fluvial deposits of the Argentona stream, Figure 6.</p> <p>In collaboration with Montpellier University:</p> <ul style="list-style-type: none"> <li>- Spectral Gamma Ray measurements have been done in 10 different boreholes to evaluate the possible variability of the sedimentology and the localization of the clay rich layers.</li> <li>- Magnetic susceptibility measurements have been performed in almost all the</li> </ul>	<p>Albert Folch, Laura del Val,  <b>Linda Luquot, Maarten Saaltink, Jesus Carrera, Enric Vazquez</b>, Jordi Garcia-Orellana, Sheila Fernandez, Carlos Casanova, Laura Martínez, Joaquim Soler, Pilar Queralt, Nuria Ferrer Ramos, Valentí Rodellas, Alex Marcuello, Juan José Ledo, Fabian Bellmunt, Jean-Raynald de Dreuzy, Olivier Bour, Hugo Le Lay, Phillipe Pezard, Harold Auradou, Alexis Shakas, Leonor Rodriguez Sinobas, Javier Benitez, John Selker, Frank Selker</p>



borehole for the same objective. Nevertheless, for susceptibility measurement as well as for the resistivity measurement, only the data obtained in the shorter wells (those without electrical tomography electrodes) are usable for data processing. The magnetic susceptibility and resistivity measurement performed into the deeper wells, with electrical tomography electrodes are useful to determine and validate the localization of each electrode. So, resistivity measurements have been performed in almost all the boreal to determine the seawater intrusion or the localization of the electrical tomography electrodes.

- Acoustic waves loggings have also been done to determine the Vp parameters and evaluate the rock porosity. These measurements have been performed in 4 different wells as a preliminary test to evaluate the acoustic waves response through the PVC tubing.
- Finally, up to know, high frequency repeated formation conductivity logging have been performed in two different borehole in May 11th (21 logs), July 15th (10 logs) and August 3rd (10 logs) to evaluate how the pore fluid conductivity changes in short time period which can locally give us some information on local fluid flow (Figure 3).

Vertical Electric Resistivity Tomography profiles have been performed between the boreholes, allowing a first identification of the fresh-salt water interface at a very high spatial resolution (Figure 4).

Passive Distributed Temperature Measurements have been performed along the Fiber Optic cable. The first results provide high temporal and spatial resolution data. During a second experiment the Fiber Optic cable was used as active sensor by applying a constant voltage through the steel armour with a variable transformer (Carroll & Meynell, United Kingdom). All measurements – with a sampling resolution of 25 cm and an integration time of 10 s - were taken with the ULTIMA-XT DTS unit (SILIXA Ltd., UK, Hertfordshire) of the H+ (Univ Rennes) (Figure 5)

Finally, periodically electroconductivity profiles in each piezometer were recorded with a CTD-Diver (Schlumberger). The measurements provide temporal and spatial information on the position of the mixing zone of the fresh-salt water interface in each borehole, and will be use to validate the results from the above mentioned methods.

**WP 6: Databases and GIS**  
 Tools for hydrochemical data interpretation 3D geological analysis and modelization have been integrated in to the GIS platform. Sedimentological data from the boreholes have been incorporated into the GIS.

Enric Vazquez,  
 Violeta Velasco,  
 Alejandro Serrano

**Nota:** Cree tantas filas como necesite. En caso de incluir figuras, cítelas en el texto e insértelas en la última página  
 \*Resalte en negrita las realizadas por el /los IPs

**E2. Problemas y cambios en el plan de trabajo**

Describe las dificultades y/o problemas que hayan podido surgir durante el desarrollo del subproyecto, Indique cualquier cambio que se haya producido respecto a los objetivos o el plan de trabajo inicialmente planteados, así como las soluciones propuestas para resolverlos. **Extensión máxima 1 página**

- 1) Luit Jan Slooten left the Project, so that we could not continue the PROOST development. To remediate the problem, we have shifted to the KRATOS platform.
  - 2) Linda Luquot left UPC to be part of CSIC. Her IP role at UPC has been taken by Albert Folch.
- We are lacking a DTS system. We tried to use the one available at UPM. They helped us in the set-up of the Optical Fiber, but have not been able to lend us the DTS. Instead, we are usind the one from the University of Rennes. We are now trying to get a second hand one.



**Nota:** Si es el **subproyecto que coordina**, rellene en este apartado también los problemas o cambios en el plan de trabajo relacionados con la coordinación del proyecto

**E3. Colaboraciones con otros grupos de investigación directamente relacionadas con el subproyecto**

Señale la participación del **subproyecto** en su desarrollo. Relacione las colaboraciones con otros grupos de investigación y el valor añadido para el proyecto coordinado. Describa, si procede, el acceso a equipamientos o infraestructuras de otros grupos o instituciones.

- Fiber Optics Distributed Temperature Measurements: the H+ research group of Rennes University provided technical assistance during the execution of the field experiments devoted to the deployment of the Fiber Optics installation. They also contributed to the experiments with their Fiber Optics equipment: ULTIMA-XT DTS unit (SILIXA Ltd., UK, Hertfordshire), DCM Fusion Splicer Micro Core (Sumitomo Electric, Japan), Temperature probes and additional material for the fusion of the fibers and the correct implementation of the calibration baths (Olivier Bour, Hugo Le Lay). Jean-Raynald de Dreuzy and Tanguy Leborgne help us with the mathematical modeling tasks.
- Harold Auradou and Alexis Shakas from FAST (CNRS, Univ. de Paris Sud) help us with geophysics and OF installation.
- Leonor Rodriguez Sinobas and Javier Benitez from UPM help us with OF installation.
- John Selker and Frank Selker help us with OF technology.
- University of Montpellier: Philippe Pezard from Montpellier University already came 3 times to the Argenton field site to perform different borehole measurements (see section E1). He came with two students and one engineer. They brought their own logging materials to perform the data acquisition.-
- Universidad Complutense de Madrid: Two researched of this university (professor and postdoc) help us during the installation of the fiber optics in each piezometer and along the field site. They brought their own equipment for the installation fiber optic cable (Splicer) and validation of the installation (DTS unit).

**E4. Colaboraciones con empresas o sectores socioeconómicos directamente relacionadas con el subproyecto**

Relacione las colaboraciones del **subproyecto** con empresas o sectores socioeconómicos y el valor añadido para el proyecto coordinado, señalando la transferencia de conocimientos o resultados del mismo.

We have had direct support from SIMMAR (mixed Public-private Company to manage waste water and other public services in the Maresme county) who manages the WWTP of Mataró and who has provided access to their installations to host the most sensitive equipment (see, e.g., Figure 3) and provided electricity (Eva Torrecillas de Pedro). They report to the Consejo Comarcal del Maresme (Maresme County Council).

We have also interacted with the Catalanian Water Agency and the Argenton municipality for permits.

All of them have collaborated selflessly. We expect to partially return through a presentation toward the end of the project as well as sharing with them all project reports.

**E5. Actividades de formación y movilidad de personal directamente relacionadas con el subproyecto**

Indique las actividades de formación y movilidad de personal relacionadas con el desarrollo del **subproyecto**. Además, si procede, debe indicar las actividades realizadas en colaboración con otros grupos o con actividades de formación en medianas o grandes instalaciones.

	Nombre	Tipo de personal ( <i>becario, técnico, contratado con cargo al subproyecto, posdoctoral, otros</i> )	Descripción de las actividades de formación o motivo de la movilidad
2	Sheila Fernández	becario	Cargese workshop
3	Joaquim Soler	otros	Cargese workshop
4	Laura Martínez	otros	Cargese workshop



5	Berta Gómez	otros	Cargese workshop
6	Linda Luquot	posdoctoral	Cargese workshop
7	Jesus Carrera	Funcionario	Cargese workshop

**Nota:** Cree tantas filas como necesite

#### **E6. Actividades de internacionalización y otras colaboraciones relacionadas con el subproyecto**

Indique si el **subproyecto** ha colaborado con otros grupos o si ha concurrido, y con qué resultado, a alguna de las convocatorias de ayudas (proyectos, formación, infraestructuras, otros) de programas europeos y/o a otros programas internacionales, en temáticas relacionadas con la del proyecto coordinado. Indique el programa, socios, países y temática y, en su caso, financiación recibida.

Out of the collaboration with Rennes and Montpellier, we applied for an ITN network (ENIGMA) in which Argenton was one of the project field sites. The proposal focused on the use of geophysical data for site characterization and was coordinated by CNRS Rennes. Partners included CSIC (Barcelona, ES), Helmholtz Centre Jülich FZJ (DE), Helmholtz Centre for Environmental Research UFZ (DE), University of Liège (BE), University of Tübingen (DE), University of Copenhagen (DK), University of Lausanne (CH), University of Neuchâtel (DE),  $\mu$ QuaS (UK), and ITASCA Consultants (FR). The proposal was submitted in January, but was denied in May (the score was 91.2%),

## **F. Difusión de los resultados del subproyecto**

Relacione **únicamente** los resultados derivados del **proyecto coordinado o del subproyecto** especificando aquellas que son resultado de la colaboración entre los subproyectos

#### **F1. Publicaciones científico-técnicas (con peer-review) derivadas del proyecto y patentes**

Autores, título, referencia de la publicación...\*

\*Resalte en negrita las realizadas por el /los IPs

#### **F2. Asistencia a congresos, conferencias o workshops relacionados con el proyecto.**

Nombre del congreso, tipo de comunicación (invitada, oral, póster), autores

Sheila Fernández López, Jesús Carrera Ramírez, Leonor Rodríguez Sinobar, Javier Benitez, Riccardo Rossi, and Antonia Laresse de Tetto, Analysis of seawater flow through optical fiber. EGU2015

Laura Martínez-Pérez, Linda Luquot, Jesús Carrera, 2015. Methodology proposal to characterize the THM properties of porous media during chemical reactions. "Congreso": summer school on "Flow and Transport in Porous and Fractured media: Development, Protection, Management and Sequestration of Subsurface Fluids". Fechas: 20/07/2015 - 01/08/2015

Sheila Fernández López, Jesús Carrera Ramírez, Leonor Rodríguez Sinobar, Javier Benitez, Riccardo Rossi, Antonia Laresse de Tetto. Study of seawater flow using optical fiber in Argenton (Spain). Summer school "Flow and Transport in Porous and Fractured media : Development, Protection, Management and Sequestration of Subsurface Fluids" ( 20 Julio 2015 - 1 Agosto 2015)

#### **F3. Tesis doctorales finalizadas relacionadas con el proyecto**

Nombre del doctor, director de tesis, título, calificación, organismo...

Cuatro en progreso (Laura del Val, Joaquim soler, Sheila Fernández and Laura Martínez)





**F4. Otras publicaciones derivadas de colaboraciones mantenidas durante la ejecución del proyecto y que pudieran ser relevantes para el mismo, así como artículos de divulgación, libros, conferencias.**

Autores, título, referencia de la publicación...

Sheila Fernández, "Seawater Intrusion Characterization", Seminar of the HydroGeology Group Subterránea, 5 de marzo de 2015, Barcelona.

Joaquim Soler, "Water Mixing Approach (WMA) for reactive transport modeling applied in advection dominated problems", Seminar of the HydroGeology Group, 26 de Marzo de 2015, Barcelona.



Figure 1. Field site Riera Argenta. Distribution of Fiber Optics cable.

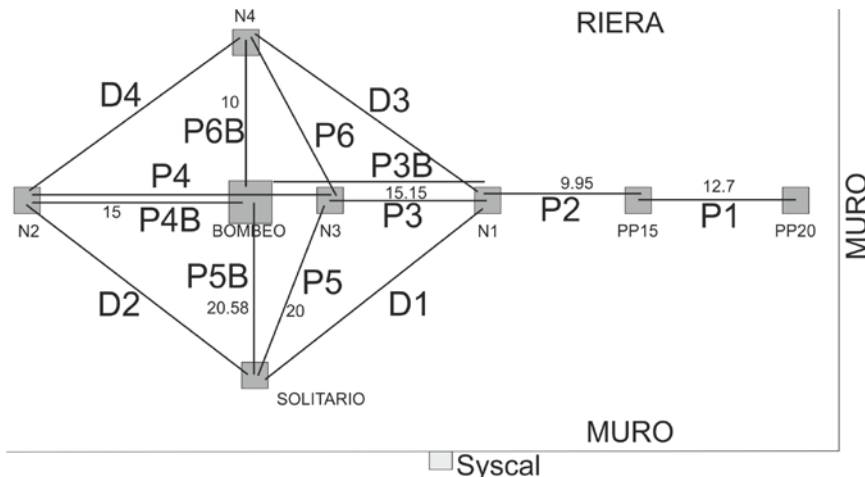
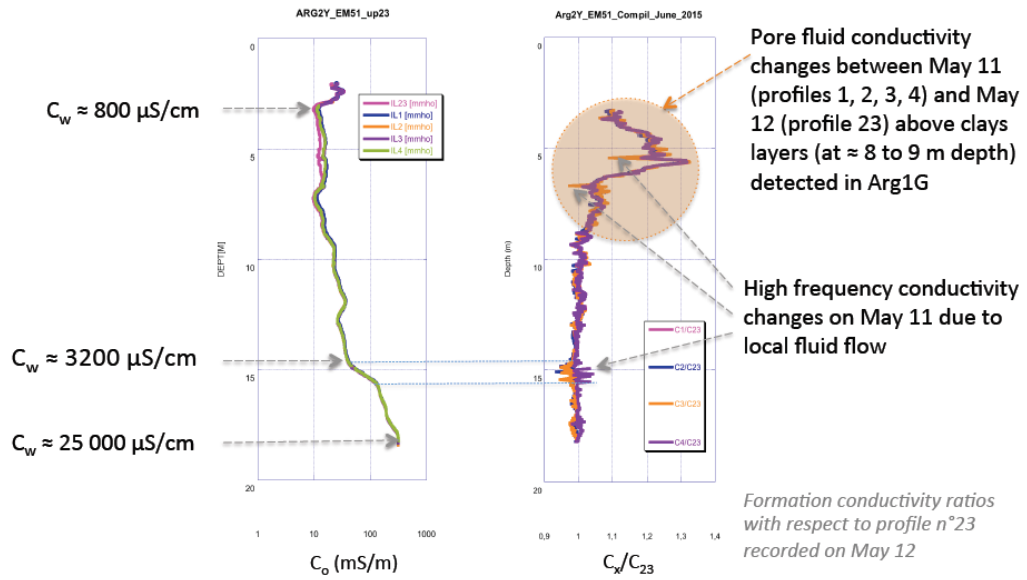


Figure 2. Distribution of wells equipped with downhole electrodes and distribution of Vertical Electric Resistivity Tomography measurements.



(the pore fluid conductivity  $C_w$  is derived neglecting  $C_s$  at this stage and using  $\phi=0.35$  hence  $F=8$ )

Figure 3: Repeated (every 10 minutes) formation conductivity logging (May 11&12).

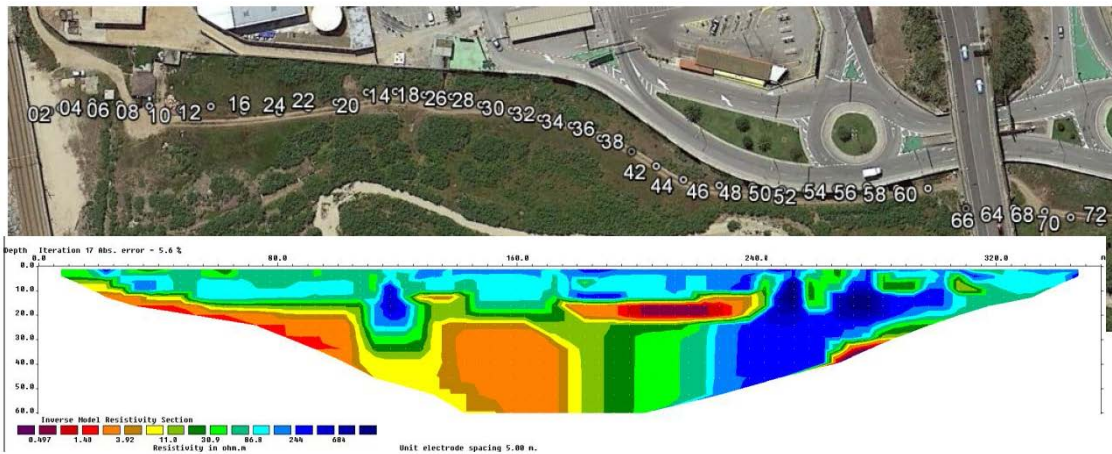


Figure 4. Preliminary ERT to facilitate well location

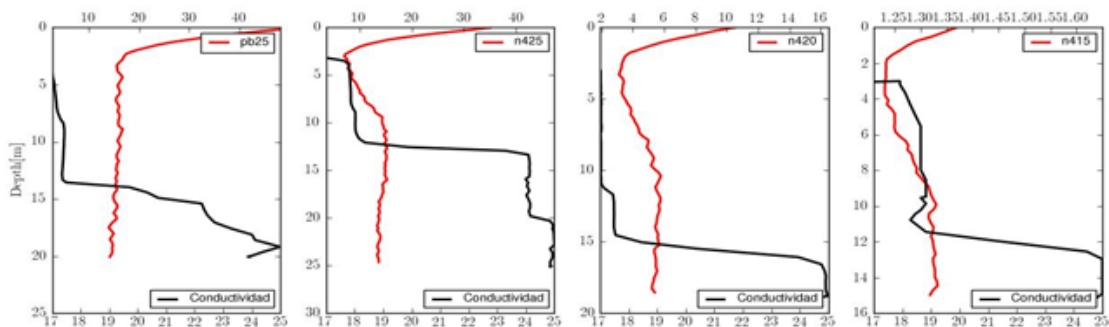




Figure 5. Preliminary results. Vertical Temperature and EC profiles in four of the boreholes

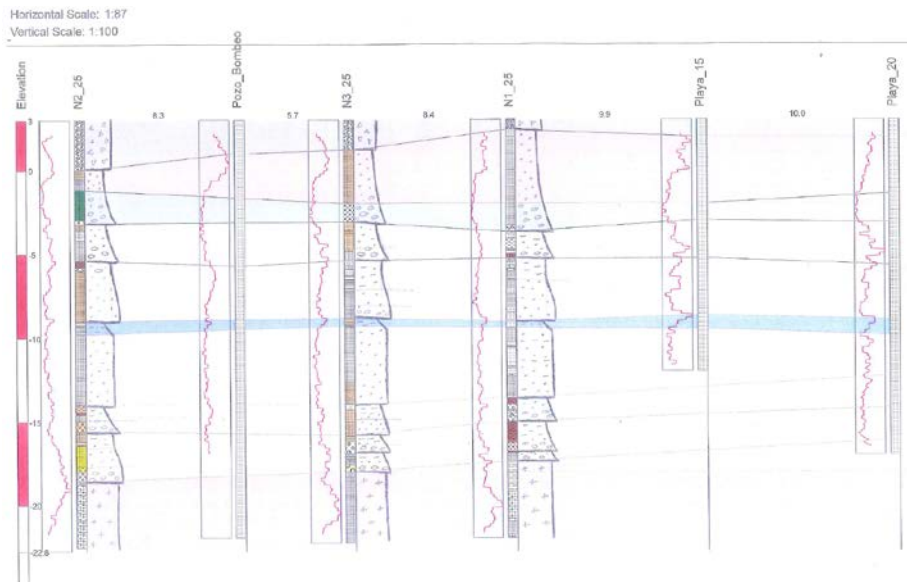


Figure 6. Longitudinal geological cross section of the Argentona stream site