IN THE MED

Innovative and Sustainable Groundwater Management in the Mediterranean

# Deliverable 2.1. Report on the integrated and innovative high-resolution monitoring strategies in the case studies

**VERSION 1.0**

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

**Acknowledgment**: This project is part of the PRIMA Programme supported by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 1923.

**Disclaimer**: The content of this publication is solely responsibility of the authors and it does not represent the view of the PRIMA Foundation.

**DOI**: 10.5281/zenodo.5348224.

# Project Information

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|---|---|---|---|
| Project Title | Innovative and sustainable groundwater management in the Mediterranean | | |
| Project Acronym | InTheMED | Grant Agreement Number | 1923 |
| Program | Horizon 2020 | | |
| Type of Action | Water RIA – Research and innovation Action | | |
| Start Data | March 1, 2020 | Duration | 36 months |
| Project Coordinator | Universitat Politècnica de València (UPV), Spain | | |
| Consortium | Universitat Politècnica de València (UPV), Spain<br>Helmholtz-Zentrum für Umweltforschung (UFZ), Germany<br>Università degli Studi di Parma (UNIPR), Italy<br>Boğaziçi Üniversitesi (BU), Turkey<br>Centre de Recherches et des Technologies des Eaux (CERTE), Tunisie<br>Technical University of Crete (TUC), Greece<br>Associacao do Instituto Superior Tecnico para a Investigaçao e Desenvolvimiento (IST-ID), Portugal | | |

# Document Information

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|---|---|---|---|---|---|
| Deliverable Number | D2.1 | Deliverable Name | | Report on the integrated and innovative high-resolution monitoring strategies in the case studies | |
| Work Package number | WP2 | Work Package Title | | Innovative Monitoring and Data Analyses in the MED | |
| Due Date | Contractual | February 28, 2021 | Actual | August 31, 2021 | |
| Version Number | 1.0 | | | | |
| Deliverable Type | Other | Dissemination Level | | Public (PU) | |
| Authors | Seifeddine Jomaa and Rafael Chavez | | | | |
| Reviewer(s) | | | | | |

# Document History

| Version | Date | Stage | Reviewed by |
|---|---|---|---|
| 0.1 | 31.08.2021 | | |

# 1. Summary

This report synthesises the progress of Task 2.1 entitled "**Implementation of an innovative high-resolution monitoring**" (**Lead IST-ID**/ participants: UPV, UFZ, TUC, UNIPR, CERTE and BU), (Month 1–Month 12) during the first year of InTheMED project duration. InTheMED project considers implementing advanced technology to monitor groundwater level and quality as an ultimate priority since the beginning of the project. The different case studies have benefited from these emerging monitoring technologies, even though the covid19 has considerably delayed the monitoring design, purchase, and installation of the new devices in the five case studies. The design and implementation of high-resolution monitoring strategies were conducted closely with Task 4.1 "**Systems characterisation, stakeholder mapping and governance analysis**". A first impression of the specific groundwater problems in the five case studies was developed among the local coordinator of each case study and key stakeholder groups. Then, the alignment between the main problems of each groundwater system, stakeholder objectives and existing monitoring network was conducted. Finally, different innovative monitoring strategies and their implementation requirements using the high-resolution monitoring approach were listed and discussed. It is worth mentioning that the implementation of the high-resolution monitoring approach was affected for all case studies by the covid19 pandemic and its measures.

# 2. Introduction and objectives

An effective evaluation of groundwater and surface water quality depends on the number of assessed parameters and their sampling frequencies and spatial coverage. Low-resolution and irregular (limited in time) grab sampling cannot capture fine dynamics of water quantity and quality status, resulting in large uncertainties in the groundwater functioning. The recent development of high-frequency optical sensors (Rode et al., 2016) has enabled monitoring solute concentrations at sub-hourly time scales, relevant for process understanding and guiding efficient management practices. Here, an innovative monitoring scheme will be used to control groundwater quantity and quality for each case study. This new monitoring strategy was designed combining grab-sampling (biweekly) and High-Resolution Monitoring Approach (HRMA, very tight measures: sampling interval lower than one hour). To complement the information provided by the traditionally spatially sparse grab sampling measurements, an innovative monitoring and characterisation approach using the HRMA and geophysical methods was considered. Geophysical data will serve to deduce aquifer properties, both for the solid and fluid phases, through an inversion procedure (Azevedo and Soares, 2017). The result will be a better understanding of groundwater system dynamics that will contribute critical information for the smart models of WP3. This method will be first implemented in the Portuguese case study, where conventional sampling and resistivity data exists, and later extended to other sites. The hotspots in each case study, which was (for some case studies) and will (for other case studies) be defined with close interaction with stakeholders and simultaneously with Task 5.1 in WP5, will be prioritised considering stakeholders inputs. The real-time data will be synchronised with the DSS tool (WP6) and used for the early-warning system. HRMA will be made available almost in real-time to the community through the InTheMED portal and other public domain databases (Task 2.4).

### 2.1.1. Objectives

Either grab-sampling or HRMA or combined methods will be implemented at the real sites to assess specific parameters of interest in terms of spatial and temporal dynamics. The hotspots in each case study will be prioritised in this task depending on the specificity of each site and the suggestion of stakeholders. The specific objectives of Task 2.1 are:

1. To present the beneficial aspects and consideration of using HRMA,
2. To give some hints on budget calculation and distribution,
3. To list potential companies and sensors that can be considered on the implementation of HRMA in the case studies.

### 2.1.2. Beneficial aspects and consideration of using HRMA

There are numerous beneficial aspects of using HRMA. However, several considerations should be followed before the monitoring design to ensure sustainability. Both aspects and considerations of using HRMA are detailed below.

### 2.1.2.1. Beneficial aspects of using HRMA

Testing the set of specific high-resolution optical sensors (Dupas et al. 2016, Rode et al. 2016) at the lab and field scales during the project will provide recommendations for the combination of proximal and remote monitoring devices for effective groundwater management in the Mediterranean groundwater systems. Recently, it has been proven the HRMA to be a sound technique to monitor water quantity and quality parameters, especially under changing environmental conditions such as the Mediterranean region. So far, the Mediterranean region is known as a relative data scare region due to the lack of systematic monitoring and data sharing policy. Also, rare high-resolution monitoring networks have been established in the Mediterranean basin, serving as a reference and long-term Terrestrial Observatory Network. The InTheMED team, together with partners from other PRIMA funded projects, will provide a significant step forward in that direction, where a continuous and HRMA will be developed in some typical case studies covering complementary groundwater problems in the MED region (Table 1 and Figure 1), known with clear water scarcity problem being already affected by climate change.

**Table 1**. Summary of five case studies and their key groundwater problems. P and T refer to Precipitation and Temperature, respectively.

| Characteristics | Requena-Utiel, Spain | Tympaki, Greece | Castro Verde, Portugal | Grombalia, Tunisia | Konya, Turkey |
|---|---|---|---|---|---|
| Size ($km^2$) | 1360 | 55 | 30 | 430 | 62000 |
| Population | 30,000 | 25,000 | 7,276 | 48,314 | ~3,000,000 |
| Location | Inland | Coastal | Inland | Coastal | Inland |
| Mean P & T ($mm\ y^{-1}$/ºC) | 440/13 | 500/15 | 567/16 | 360/20 | 387/12 |
| Principal groundwater users | Agriculture, urban | Agriculture | Urban, mining | Agriculture, industry, tourism | Agriculture, urban |
| Overexploited | Yes | Yes | No | Yes | Yes |
| Groundwater pollution | No | Nitrate, salinity | Mine wastes | Nitrate, salinity | Nitrate, salinity |

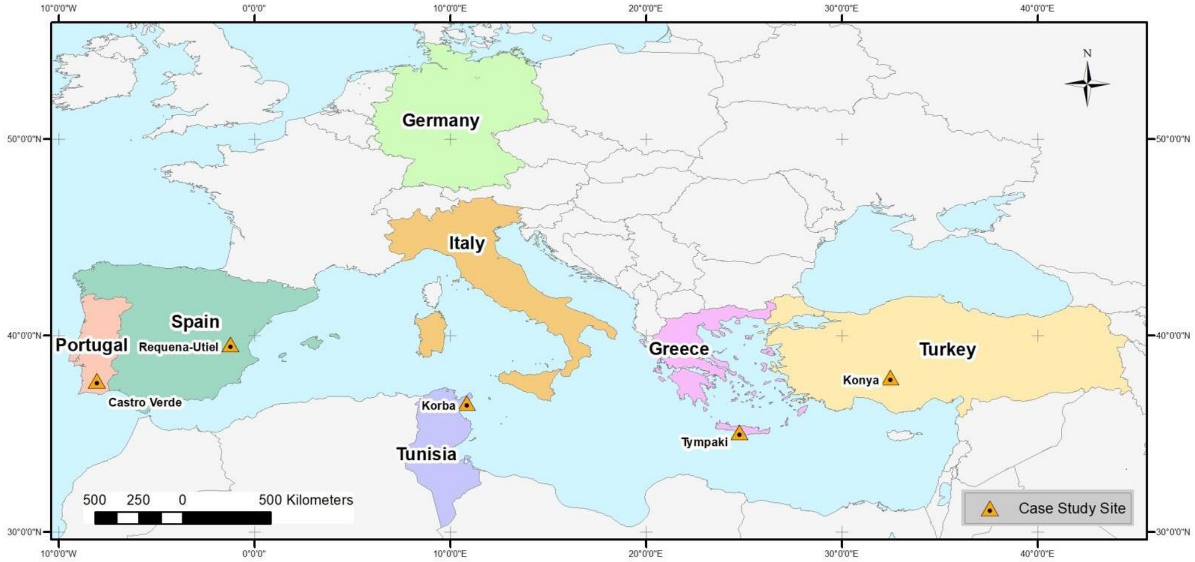


**Figure 1.** Geographical Location of the five case study areas of InTheMED project.

Representative aquifers were considered in InTheMED project: the Portuguese Castro Verde aquifer is under pressure by nearby mining activities, the Spanish Requena-Utiel aquifer has shown consistent water declines over the last 10 years after the beginning of vineyard irrigation, a crop that has been dry farmed in the past; the Tunisian Grombalia aquifer suffers from salinization due to saltwater intrusion plus continuous groundwater depletion owed to agricultural, industrial and tourism activities; the Greek Tympaki aquifer on the island of Crete presents saltwater intrusion up to 2 km inland; and the Turkish Konya aquifer, a large aquifer underlying a closed basin in central Anatolia is suffering from high levels of salinity and nitrate contents and severe water decline due to intensive water use for irrigation.

#### 2.1.2.2. Consideration for selecting groundwater monitoring sensors

The main consideration prior to any implementation of HRMA is to clarify our monitoring targets, which mainly depend on the site characterisation, former knowledge, and emerging concerns. To better reshape this consideration, it is essential to answer the following three questions:

- **What do we measure?** The answer to this question depends on the system feature, concerns and available technology.

- **Where do we measure?** The answer to this question depends on the source and its spatial distribution, geology, secure site selection, ease of access, available power supply, and good connection with the site owner.

- **How often do we measure?** The answer to this question depends on the time response of the GW system (commonly, 1-hour is recommended for groundwater monitoring). Note that the more often we measure, the more efforts and costs should be dedicated.

### 2.1.3. Budget calculation and distribution

A successful and sustainable design of HRMA approach depends significantly on the budget calculation and distribution. Therefore, before any investment in new devices and methods, the budget should be well calculated and carefully distributed among the different components of the monitoring design. The different items that the original budget should consider are:

- Installation cost (which often require a private company to drill the well, resulting in additional cost such as recommendation and logistics etc.),

- A connection cable is costly (on average 1-m of cable costs 10 euro) and should be considered from the beginning of the calculation. In some cases, it is possible the price of the cable can be close to the sensor price,

- Telemetry system (needed or not: often needed for deep well and not recommended for a sallow well),

- The number of parameters required for the monitoring (one port, 4-6 replaceable mobile ports).

- Required pressure range of the sensor. Always it is fixed and not replaceable. Each sensor has its unique pressure range. For instance, In-Situ Aqua Troll 200 is operating at 6-351 m range. While the In-Situ Aqua Troll 400 is operating in the range 1-76 m.

Below is the list of companies and their list of parameters that were discussed with the project partners as potential sensors can be considered in the design of the monitoring strategies and implementation of HRMA in each case study (Table 2). Also, a short discussion on the advantage and price category of each option were briefly listed in Table 2.

Table 2. List of companies, parameters and characteristics of each category of sensors.

| Company | Parameters | Advantage | Price category |
|---|---|---|---|
| YSI-EXO<br>https://www.ysi.com/exo2<br> | Multi-parameter probes with 7 sensors including: Water Depth, Temperature, Electrical Conductivity, Dissolved oxygen, pH, Total algae (blue-green algae and chlorophyll in one sensor), Turbidity | Very complete sets of parameters allowing a very detailed understanding of the system. Also it permits to develop a good proxy investigation on how the high resolution data can be used as indicators to reconstruct continuous records of parameters, which are traditionally grab-sampled such as Phosphorus concentration | Expensive |
| In-Situ-AquaTroll<br>http://www.in-situ-europe.com/<br> | pH, water level, Dissolved Oxygen, Temperature and Electrical Conductivity | Has the key set of parameters combination needed for good assessment of groundwater quality and quantity | Moderate |
| Onset-Hobo<br>https://www.onsetcomp.com/products/water<br><br>Vanessen-diver<br>https://www.vanessen.com/products/water-level<br> | 2 Separate options: for groundwater Quantity (Water depth) or Quality (Electrical Conductivity and water temperature) | Usually only one option is implemented depending on the specific problem of the groundwater system (either quantity or quality). | Relatively cheap |

## 3. Conclusions

Adopting new high-resolution techniques for water-quality monitoring and water quantity-accounting using specific sensors and benefiting from new technology development are valuable for processes understanding and scientific decision-making tools development. InTheMED aims to initiate continuous and high-resolution monitoring strategies at case studies of the five typical sites in the Mediterranean region, which together with other initiatives can be considered as Reference Terrestrial Observatories in long-term perspective after the project end. The long-term objective of this project is to generate common and online hydrological, hydrogeological and water quality data sets between the different case studies and beyond to understand better the effect of anthropogenic, land use and climate changes on groundwater functioning. Also, it is worth considering that the HRMA is expensive and laborious and needed additional maintenance and recalibration of the sensors from time to time and a cleaning system to ensure accurate measurement. Also, the specificity of each case study and objective of the monitoring should be aligned early with the decision-makers expectation to choose better the proper monitoring strategies and critical sets of parameters. The literature well reported (e.g., Jomaa et al. 2018) that the combination of a continuous long-term grab sampling monitoring and the implementation of high-resolution monitoring approach for a given period is the optimum solution. Long-term groundwater level records are crucial to investigate groundwater trends and their controlling factors. This ensures to track the long-term trends and trajectories of the assessed phenomena and improve the physical understanding of the system at the time scale of processes. Details on the optimum monitoring strategies of the five cases studies will be investigated and discussed over the course of the project duration. This will be conducted considering the system boundaries of each case study and inputs from different stakeholders groups collected during the Living Labs. Also, a cost-benefit analysis will be, in parallel, carried out to better guide the decision making of the optimum monitoring design needed in each case study.

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