

D.3.3.1 – WATERCARE WQIS implementation



Document Control Sheet

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1. INTRODUCTION

The Water Quality Integrated System (WQIS) network was applied and implemented for each study area and focused on urban areas in sewers, riverine and rivers. Our innovative Water Quality Integrated System is based on a thorough knowledge of the magnitude, frequency, and impacts of microbial contamination of bathing water due to high rainfall. The system was developed to protect public health, the environment and the economic activities that rely on tourism. Its proactive approach to coastal water quality management can be applied to a variety of coastal sites characterized by extreme raining events.

The WQIS is based on real-time hydro-meteorological monitoring, a forecast model that simulates pollutant dispersion in bathing water, and a real-time alert tool that predicts potential ecological risks related to the bacterial contamination of bathing water after extreme raining events.

In the D3.1.1 Software Utilities and D3.1.2 WATERCARE WQIS deliverables, design, test, and preparation of the WQIS have been described.

After this preparatory phase, the WQIS was implemented in the Fano pilot site as described in the deliverable D.3.3.1 - WATERCARE WQIS implementation and 4.1.2– Implementation/realization of the WQIS in the pilot site.

The experience gained in the implementation phase of the WQIS in the pilot site has been transferred to the various partners of the project. In particular, the connection diagrams of the equipment, the sampling strategies, and an operating manual regarding the use of the entire WQIS "ecosystem" were shared. In this regard, the authors of this deliverable would like to thank:

- Vedrana Spada, Josipa Bilic from Istrian University (Ex METRIS) for testing and implementation of the equipment in Rasa River (Pola, Croatia). It was the first installation in Croatia and the first after the pilot site. The experience gained during this implementation helped the whole

WQIS optimization process and also simplified all the remaining Croatian implementations (Split and Dubrovnik);

- Alan Blažekovic, PROMOTRONIC (Zagreb) for testing and implementation of the equipment in all Croatian sites;
- Dr. Roberto d'Andrea and Ing. Lucia Bergia, ACA (Pescara) for testing and implementation of the equipment of the Pescara site.

CNR IRBIM provided continuous remote support from the testing phase in the laboratory to the complete installation in the field and subsequent launch of the Watercare site to the production of valid data. During this operational phase CNR IRBIM also updated both the centralized database and the dashboards designed for data visualization as shown in Chapter 4 WEB presentation of sensor data of this deliverable.

2. WQIS DEVELOPMENT CYCLE

The WQIS is an IT ecosystem consisting of several interconnected and continuously interacting subsystems (Fig. 2.1). In the first subsystem (Meteorological, Freshwater, and Seawater monitoring), some activities are automatic and do not require the direct intervention of an operator, whereas other activities, such as seawater sampling and bacteriological and chemical analyses, involve human action. The flow of information stored in the WQIS database is managed by a continuously running software that processes the data by means of a forecast operational model connected to an alert tool.

These tools are the WQIS results and allow generation and delivery of FIB dispersion forecast maps, which are then used by decision makers. Therefore, the system outputs real-time data that updates historical series with new data. The alert tool notifies users of:

- system progress;
- any abnormalities in the environmental parameters;
- any hardware abnormalities detected in real time.



Figure 2.1. The WQIS IT ecosystem and the integrated subsystem.

Regarding software engineering, during the various development phases of the Watercare project, the paradigm called agile software development (ASD) was used. Agile methods are opposed to the waterfall model and other traditional development models, proposing a less structured and focused approach on the objective of delivering functioning and quality software (continuous new verifications), quickly and frequently.

An important practice through which the solution to be delivered evolves from what was only an "idea" (a concept, a proposal, a set of needs) to become a valuable product. Iterative development works through cycles of actions / activities (Fig. 2.2) that do not change, but which by repeating cyclically lead the 'raw' solution to be refined until it becomes the final product.

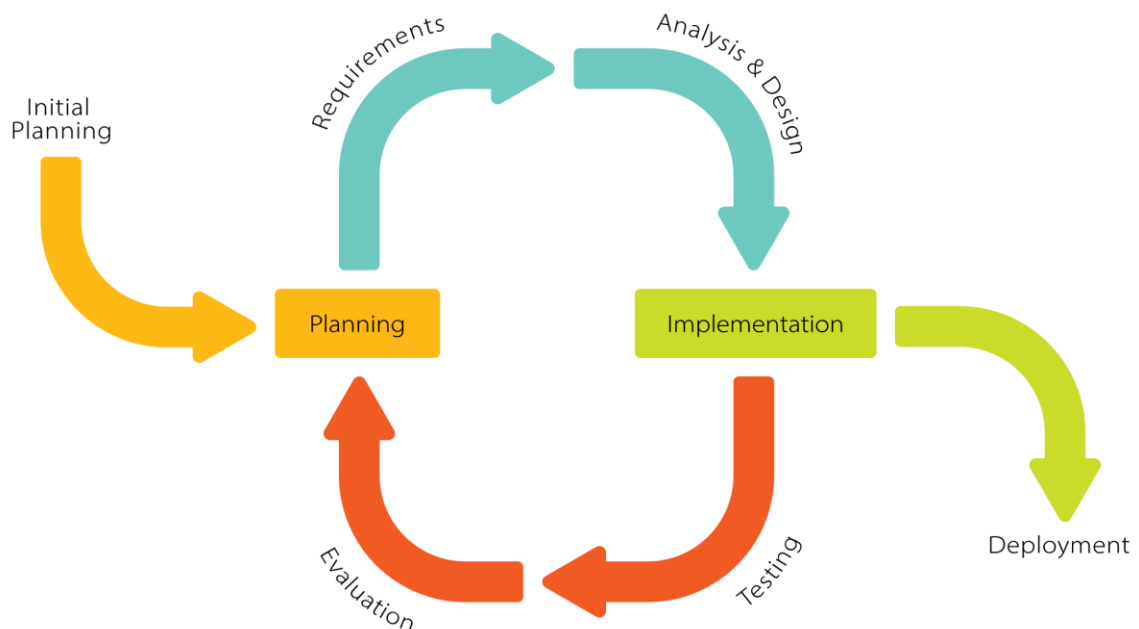


Figure 2.2 WQIS Iterative development model (modified from Wikipedia, 2021).

Some practical examples of the optimal use of agile methodologies and incremental development during the development of the Watercare project are for example: the integration of river level sensor (Arzilla Outfall-Fano pilot site) and the upgrading of Database, Alert system tool, sample Analysis script and web data presentation after the implementation of each Watercare site.

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Furthermore, thanks to the feedback from Vedrana Spada (Istrian University) it was possible to insert a new automatic sampling activation function using a set threshold of rain fallen in the previous half hour. This very useful function, not foreseen in the planning phase, has been created and tested in all Italian and Croatian Watercare stations.

With great satisfaction of all Watercare project participants, we can declare that all the objectives planned in the design phase have been achieved, considering the available budget and within the time limits set by the Watercare project.

3. WQIS CONCEPTUAL SCHEMA

In this chapter a detailed description of the individual components of the WQIS is given. In Figure 3.1 is reported the data flow scheme and it could be considered also a kind of index to the section described below, in which there are also links to other project deliverables and activity.

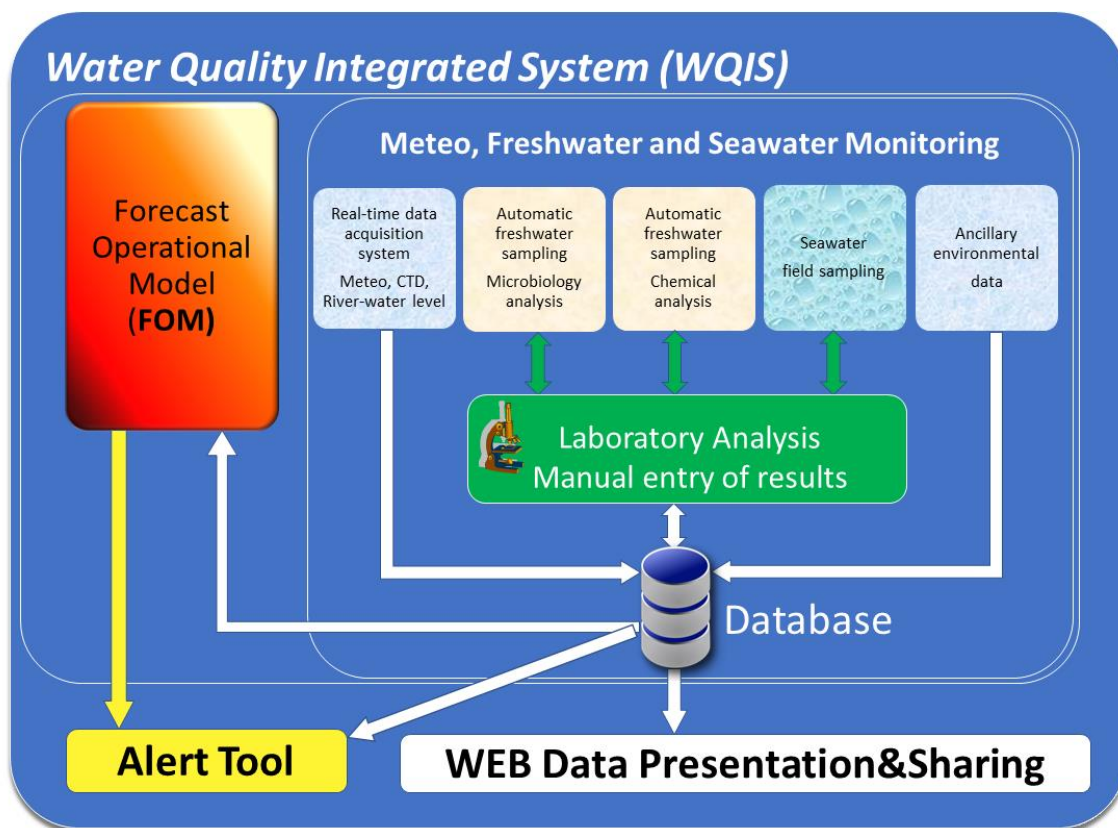


Figure 3.1. Water Quality Integrated System data flow scheme. (Penna P. et al., 2021).

3.1 Real time data acquisition system

A fundamental step concerning the plan and implementation phase was to study the subsystems and sensors, taking particular care of communication, energy consumption, physical connection, and the format of the data output. During this activity, the most delicate procedure consisted of the

implementation and test of the scripts for the management of communication, data reading and data transfer between the datalogger and each sensor.

Subsequently, a complete abstracted firmware and software was implemented: all the source codes produced in the previous step were integrated into subroutines and functions were inserted into a complete reading cycle performed every 30 minutes (the sensor reading routines are performed almost continuously and subsequently processed every 30 minutes).

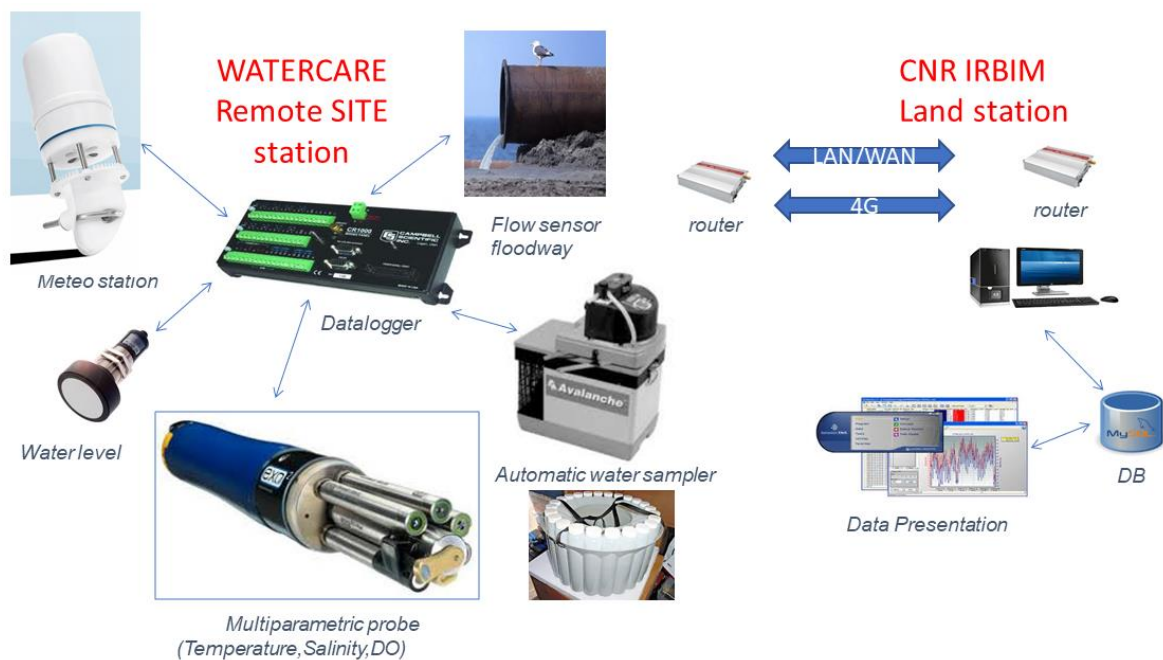


Fig. 3.1.1. Block diagram of a WQIS stations.

The real-time acquisition system includes the following equipment:

- **Campbell Scientific CR1000X** datalogger that manages the interface with sensors/actuators, data collection and remote communications.
- **Campbell Scientific ClimaVUE50** compact weather station. It measures in real-time the following parameters: wind (speed, gust, direction), air temperature, relative humidity, atmospheric pressure, solar radiation, rain gauges, lightning.
- **YSI EXO2 (or EXO3)** multiparametric probe. The sonde allows real-time river water monitoring measuring the following parameters: level, temperature, salinity, conductivity, Optical Dissolved Oxygen (concentration and saturation), turbidity, pH, redox.

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- **Teledyne ISCO Avalanche** automatic and refrigerated water sampler which takes samples (14 bottles, 900ml) for laboratory analysis of microbiological parameters of river water.
- **Siemens Probe LU240** ultrasonic level sensor (Fano only).

Nitrate and ammonia (pH, redox Fano only) are measured with a portable multiparametric sonde in water samples collected with ISCO Automatic sampler.

More details about the hardware devices used can be found at the Annex 1.

Table S1 summarizes the parameter measured for each Watercare site station and the hardware device used.

HARDWARE SENSORS	PARAMETER	FANO Arzilla Upstream	FANO Arzilla Outfall	POLA Rasa River	DUBVRONICK Neretva River	SPLIT Cetina Main	SPLIT Cetina Outfall	PESCARA Pescara River
Weather Station (ClimaVUE™50)	Wind (speed, direction, gust)	-	X	X	X	X	-	X
	Air Temperature	-	X	X	X	X	-	X
	Relative Humidity	-	X	X	X	X	-	X
	Atmospheric Pressure	-	X	X	X	X	-	X
	Solar Radiation	-	X	X	X	X	-	X
	Rain Gauges	-	X	X	X	X	-	X
	Lightning	-	X	X	X	X	-	X
Multiparameter Sonde (YSI EXO2/EXO3)	Water Temperature	X	X	X	X	X	-	X
	Salinity	X	X	X	X	X	-	X
	Conductivity	X	X	X	X	X	-	X
	Optical Dissolved Oxygen (concentration and saturation)	X	X	X	X	X	-	X
	Turbidity	X	X	X	X	X	-	X
	pH	-	-	X	X	X	-	X
	Redox	-	-	X	X	X	-	X
Level Sensor (Siemens SITRANS LU240)	River Level	X	-	-	-	-	-	-
	River Flow Sensor	Estimated by model	-	-	-	-	-	-

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Table S1. Hardware devices measured parameters and WQIS stations.

HARDWARE SENSORS	PARAMETER	FANO Arzilla Upstream	FANO Arzilla Outfall	POLA Rasa River	DUBVRONICK Neretva River	SPLIT Cetina Main	SPLIT Cetina Outfall	PESCARA Pescara River
Datalogger Campbell Scientific CR1000X		X	X	X	X	X	X	X
ISCO Avalanche Sampler		X	X	X	X	X	X	X
Power Source		230V	230V	230V	12V Battery Photovoltaic panel	230V	12V Battery Photovoltaic panel	230V

The conceptual model of the management of the acquired data is composed of different levels (Fig. 3.1.1). The datalogger firmware is responsible for interfacing with the sensors and it manages the real-time reading of the signals (analog and/or digital) output from the sensors. Data is processed and stored locally. Every 30 minutes data is then reprocessed to be collected in a single record and inserted into a pre-configured datalogger table. The Campbell Scientific’s LoggerNet software retrieves in real-time raw data from remote dataloggers and inserts it into the WQIS Centralized Database (CDB).

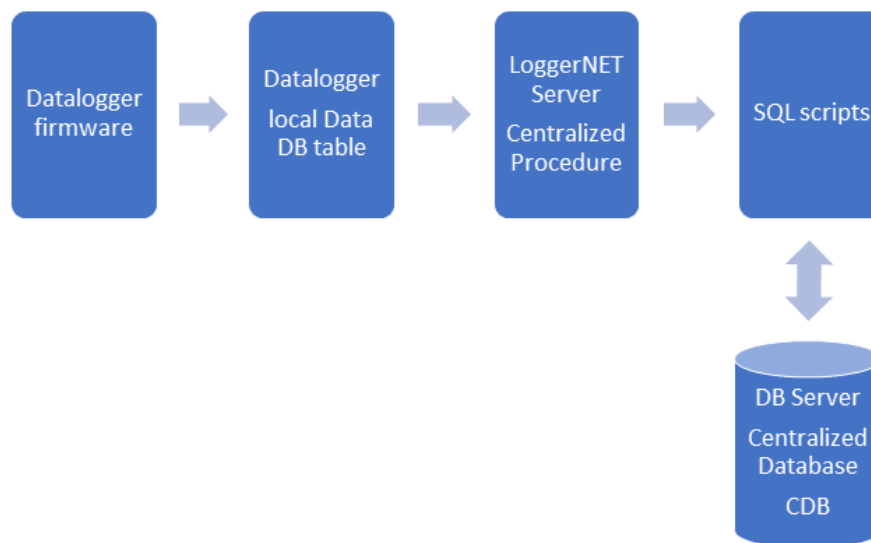


Figure 3.1.1. Block diagram of real-time data acquisition.

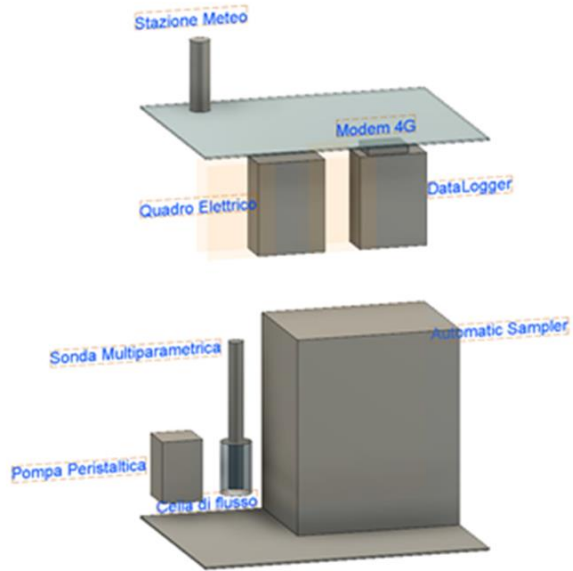


Figure 3.1.2. Concept of real-time data acquisition system.











Arzilla River outfall (FANO Pilot site)		Arzilla River upstream (FANO Pilot site)	
			
Rasa River (Pola)		Neretva River (Dubrovnik)	
			
Cetina River main-upstream (Split-Omis)		Cetina River outfall (Split-Omis)	



Figure 3.1.3. Real-time data acquisition system implemented at Watercare sites.

3.2 Automatic freshwater sampling

The Automatic freshwater sampling is detailed in the deliverable: 3.2 – Sampling Data set.

3.3 Seawater field sampling and analysis

Sampling and laboratory analyses of microbial and chemical parameters are detailed in the deliverable 3.2.

3.4 Ancillary environmental data

To ensure an exhaustive knowledge of the Fano pilot site, ancillary data were obtained from:

- a pluviol-hydrometric station (located at Santa Maria dell' Arzilla, about 10 km from the pilot site) managed by the Marche Region Civil Protection.
- Regional Agency for Environmental Protection of Marche (ARPAM) (Figure 3.4.2 and 3.4.3).
- Italian Health Ministry (Italian Ministry of Health, 2014); <http://www.portaleacqua.salute.gov.it>.
- Urbino University (time series data from 2000 to 2014) (Figure 3.4.4).

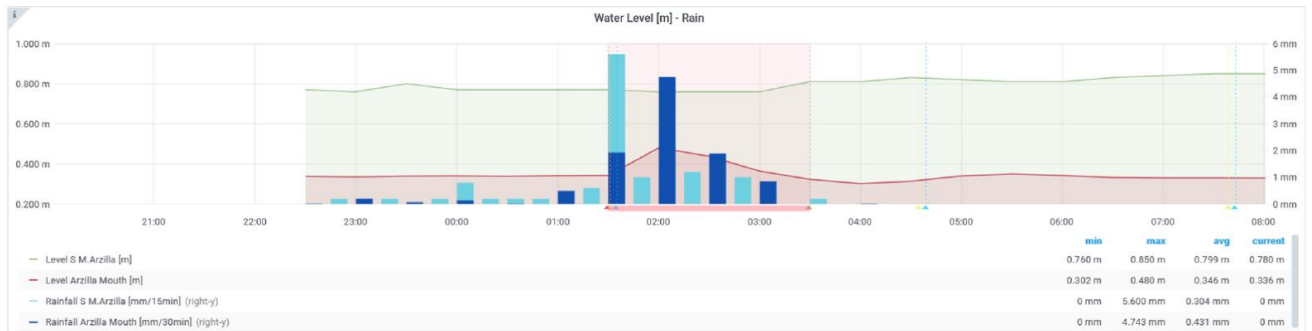


Figure 3.4.1. Rainfall temporal trend and river level measured in the stations of Fano Arzilla outfall and Santa Maria dell'Arzilla (about 10 km away based on ancillary data).

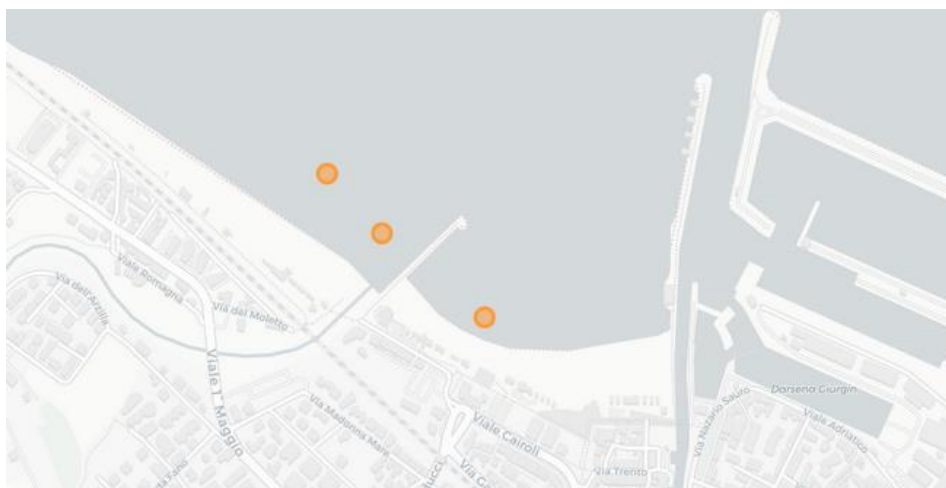


Figure 3.4.2. The ARPAM sampling points. In order from the north: IT011041013032 (Arzilla Via della Baia), IT011041013005 (30 M NORD TORRENTE ARZILLA) and IT011041013006 (SPIAGGIA LIDO 100 M SUD MOLO ARZILLA).



Figure 3.4.3. Example of ARPAM data. The sampling points IT011041013006 (SPIAGGIA LIDO 100 M SUD MOLO ARZILLA) and IT011041013005 (30 M NORD TORRENTE ARZILLA) correspond respectively to the coordinates 43.852253, 13.011380 and 43.853367, 13.009494.



Figure 3.4.4. Urbino University sampling point.

The ancillary data are fundamental for the knowledge of the rain-river-sea system located in the Arzilla basin, since before the implementation of the WQIS stations in the pilot site, there was no knowledge of local hydrodynamics. In addition, as shown in Figure 3.4.1, these data proved to be very useful for having feedback on the functioning of the rain and level sensors installed during the project and therefore they represent the validation of actual data.

In the Pescara and Croatian stations, the ancillary data were used for local validations and to obtain useful information for the purposes of the project, even though they were not integrated into the WQIS centralized Database.

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3.5 Data entry

CNR IRBIM staff has developed a web interface, named Sample Analysis (S.A), with the task of acquiring manual monitoring data, such as data from chemical and microbiological analyses performed by the authorized personnel. Samples Analysis has been developed using html, php and JavaScript language, in addition to jQuery and Datatables for interfacing with the database.

The data included in S.A are integrated into the WQIS CDB and made available for the web data visualization and for the FOM model.

The users can view and manage the data related to the site for which he is responsible. The data can be downloaded into Excel and CSV format and furthermore they can be copied to clipboard.

The samples taken by the ISCO Avalanche automatic sampler are automatically added in the WQIS CDB and they are shown directly in the web interface to simplify the insertion procedure of the data and to reduce the risk of human typing error. The chemical and microbiological parameters included in the S.A are listed in table 3.6.1. The User has access only to the data of the locations under his responsibility.

The main web page includes a list of all chemical and microbiological data collected in the WQIS sites (Figure 3.6.1). The main functions and commands are shown in Figure 3.6.2.

When automatic sampling is in progress and after each ISCO Sample, a new record will be automatically filled with the following information: timestamp, location, typology, site, sampling mode and sample. The operator can then insert the analysis results by selecting the corresponding sample record and then by clicking on the *Edit Sample* button in the command bar. The system then generates a popup window with the wizard for inserting the analysis data by the user (Figure 3.6.3).

The interface also provides the possibility to insert new manual sample records (e.g. all sampling points not directly connected to the ISCO Avalanche automatic sampler, sea sampling points or all manually collected samples) by pressing *New Sample Event* on the command bar. The user can then enter the requested information in the window popup (Figure 3.6.4) and press the *Create* button. The user can only see the values associated with the observing sites of competence.

Considering the need of some project partners to process the data locally, the possibility of exporting the S.A. data has also been enabled. Sample analysis interface provides the possibility to export the data analysis into Excel or CSV files (each line of the file is a data record. Each record consists of one or more fields, separated by commas) by pressing the *Excel* or *CSV* button in the command bar (Figure

3.6.5). It is possible to export all table records or a selection of data. Eventually, it is possible to use the same procedure to copy records in the clipboard by pressing the Copy button.

In case of errors, a record can be deleted using the *Remove* button in the command bar.

Table 3.6.1. Chemical and microbiological parameters included in the Sample Analysis interface.

Header	Description	Type / Units
Timestamp	date and time of the sampling event	UTC Time (YYYY-MM-DD HH:MM:SS)
Location	City where the site is installed	Selection form (text)
Typology	Typology of the sampling point (Sea, River)	Selection form (text)
Site	Name of the sampling site	Selection form (text)
Sampling Mode	Reporting the sampling method: Avalanche Sampler, Manual Sampling	Selection form (text)
Sample	Unique code of the sampling point	Automatic setting (text)
Analysed	Report whether the sample has been analysed	Boolean (True or False)

Sea state (waves)	Sea wave height (optional)	Numeric (m)
Sea water current	Direction of the sea water current (optional)	Selection form (cardinal points)
Salinity	The amount of salt dissolved in a body of water	Numeric
Temperature	Water temperature	Numeric (°C)
Redox	Water reduction–oxidation	Numeric (mV)
pH	Water pH	Numeric
Conductibility	Specific conductance: ability to conduct electricity	Numeric (mS/cm)
BOD₅	Biochemical Oxygen Demand	Numeric (mg/L)
COD	Chemical Oxygen Demand	Numeric (mg/L)
Turbidity	The cloudiness or haziness of a fluid caused by suspended solids that are usually invisible to the naked eye	Numeric (NTU)

Dissolved O₂ [%sat]	Dissolved Oxygen	Numeric (%)
Dissolved O₂ [mg/L]	Dissolved Oxygen	Numeric (mg/L)
Chlorophyll-<i>a</i>	blue/green substance	Numeric (µg/L)
TSS	Total suspended solids	Numeric (mg/L)
TOM	Total Organic Matter	Numeric (mg/L)
N-NH₄	Ammonia	Numeric (µM)
N-NO₃⁻	Nitrate	Numeric (µM)
N-NO₂⁻	Nitrite	Numeric (µM)
Tot - N	Total nitrogen	Numeric (µM)
Tot - P	Total phosphate	Numeric (µM)

P-PO₄	Ortho-phosphate	Numeric (µM)
<i>Enterococci</i>		Numeric (UFC/100ml)
<i>Escherichia coli</i>		Numeric (UFC/100ml)
Note	Report any comments or notes on the specific sample	Text

Logged in as Fabrizio Moro
[Logout](#)

SAMPLES ANALYSIS

From Date: To Date:

[Reload](#)
[New Sample Event](#)
[Edit Sample](#)
[Copy](#)
[Excel](#)
[CSV](#)
[Remove Sample](#)
Search:

Timestamp (UTC)	Location	Typology	Site	Sampling Mode	Sample	Analysed	Sea state (waves) [m]
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
2020-03-04 13:39:00	Pola	River	Rasa River - Pola	Avalanche Sampler	PRS01		
2020-03-03 13:10:00	Fano	River	Arzila Monte	Avalanche Sampler	AZM14		
2020-03-03 13:08:00	Fano	River	Arzila Monte	Avalanche Sampler	AZM13		
2020-03-03 13:06:00	Fano	River	Arzila Monte	Avalanche Sampler	AZM12		

Figure 3.6.1. Main page of the Samples Analysis site.



Figure 3.6.2. Description of the Main Page functions. Login information shows the name of the logged in user and the logout key. Search bar by date allows the visualization of the data in the period between the start-date (From date:) and the end-date (To date:). Quick search bar can quickly visualize records that include the keyword inserted. Command bar includes buttons for site managing, for data entry/modification and export.

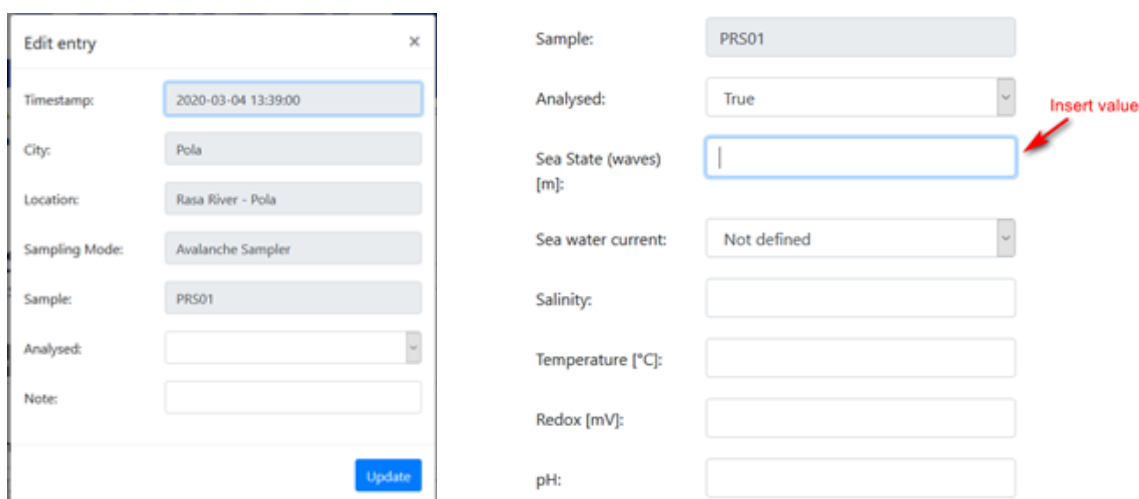
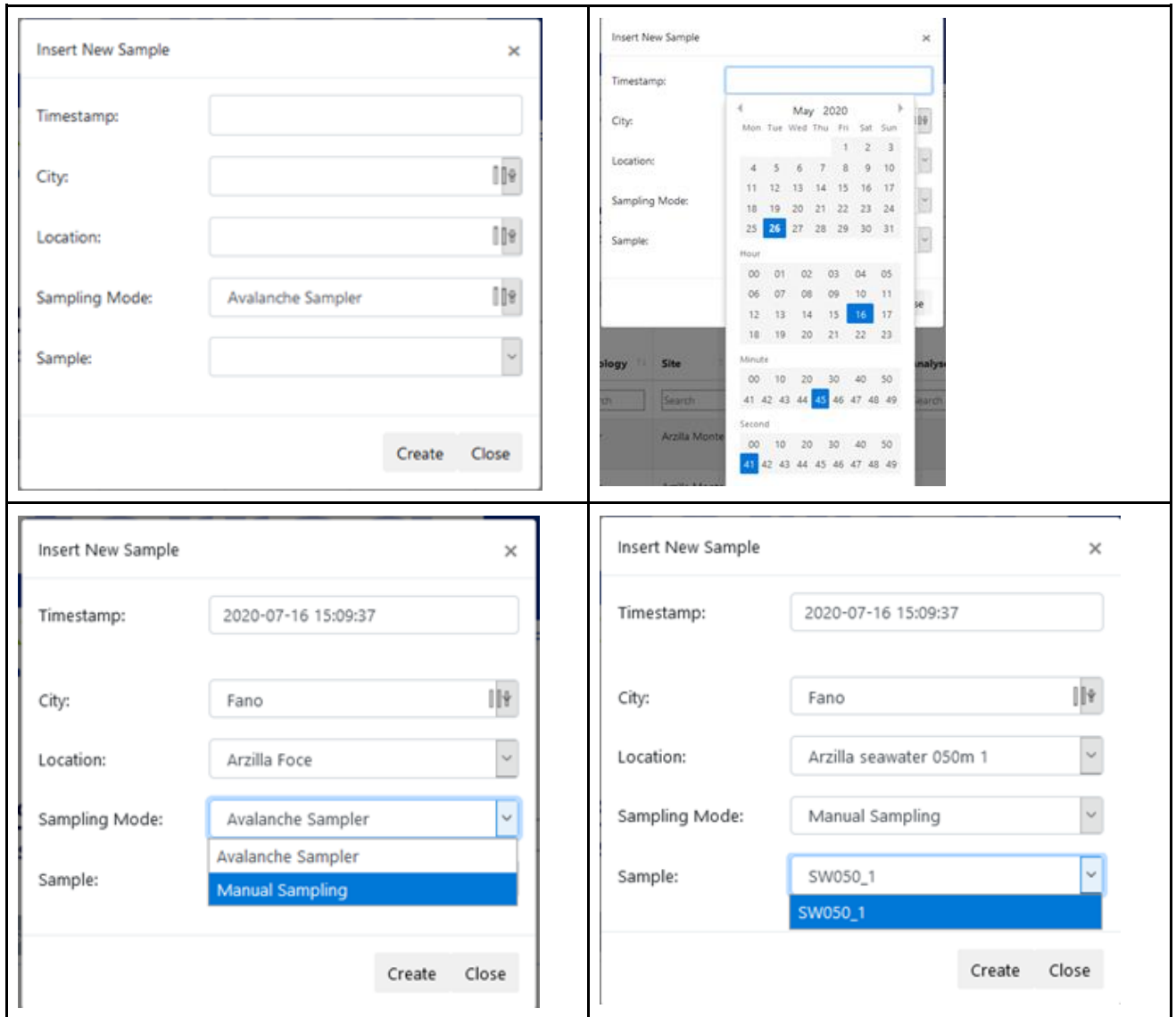


Figure 3.6.3. Example of Edit form of a sample taken from the autosampler. Timestamp, City, Location, Sampling Mode and Sample are fields auto-filled by the system.

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The figure displays four sequential screenshots of the 'Insert New Sample' form:

- Top-Left:** The form is initially empty, with fields for Timestamp, City, Location, Sampling Mode (set to 'Avalanche Sampler'), and Sample.
- Top-Right:** A date picker is open, showing the month of May 2020. The date '16' is selected.
- Bottom-Left:** The form is populated with: Timestamp: 2020-07-16 15:09:37, City: Fano, Location: Arzilla Foce, and Sampling Mode: Avalanche Sampler. The Sample dropdown menu is open, showing 'Avalanche Sampler' and 'Manual Sampling' as options.
- Bottom-Right:** The form is fully populated: Timestamp: 2020-07-16 15:09:37, City: Fano, Location: Arzilla seawater 050m 1, Sampling Mode: Manual Sampling, and Sample: SW050_1.

Figure 3.6.4. Insert New Sample form. In this example the user proceeds with the insertion of a new sample collected in the sea (point SW050_1 - Fano Arzilla) on July 16, 2020.

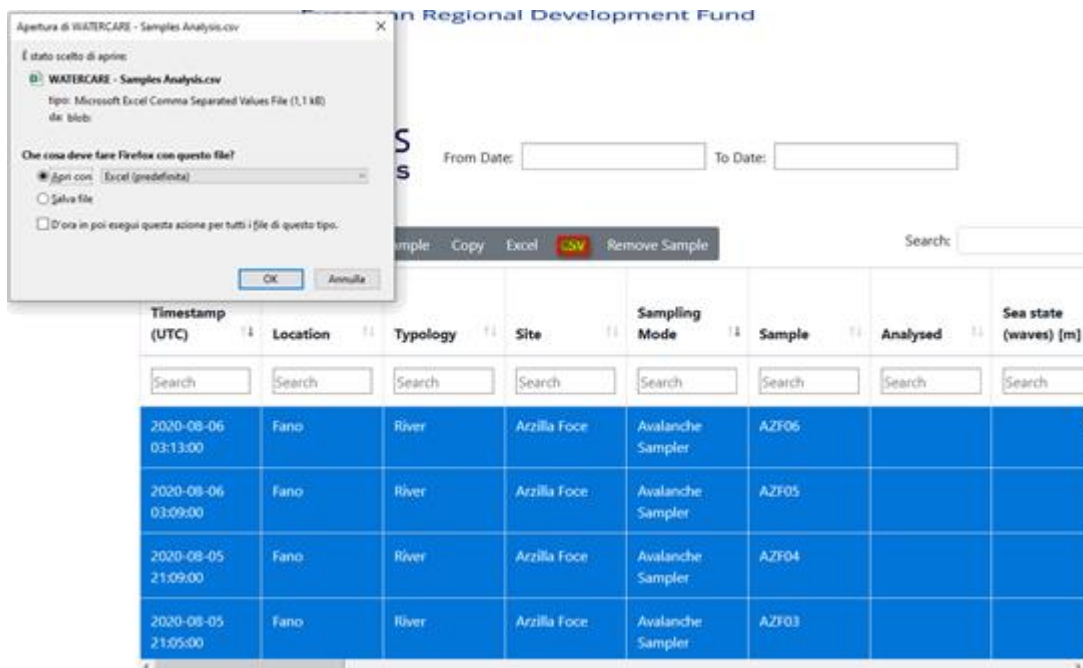
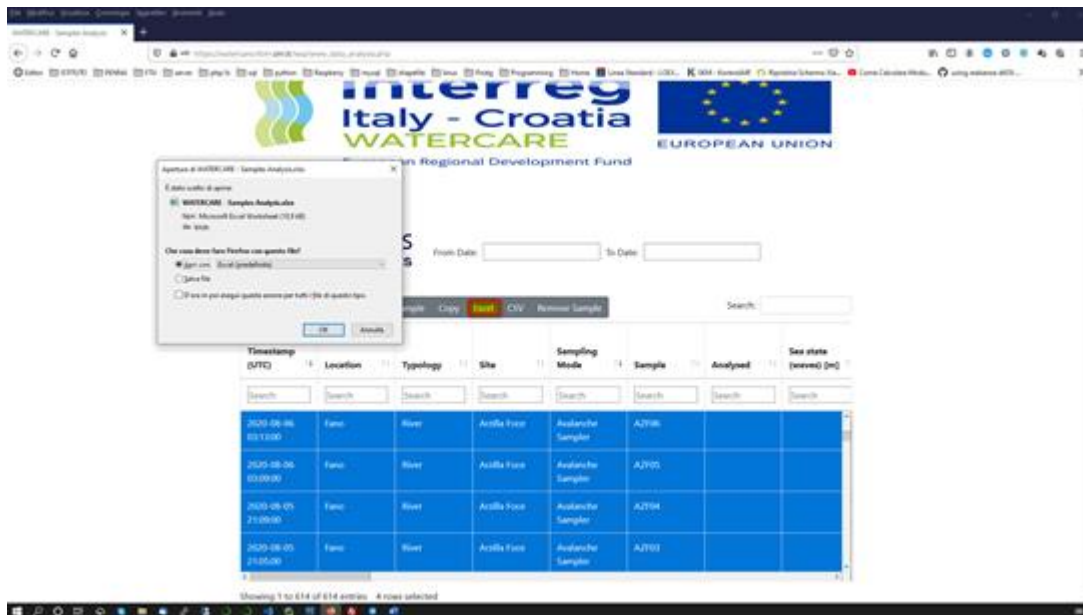


Figure 3.6.5. Excel and/or CSV export.

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3.6 Centralized database

CNR IRBIM staff has developed a centralized database (WQIS CDB) using the relational database management system (RDBMS) MySQL and it is the heart of the collection project data. (Sensors data, analysis results, ancillary data, project partners registers, access information to project websites, geolocation sampling points, etc). The interoperability of data is guaranteed using an internationally recognized vocabulary (British Oceanographic Data Centre-NERC Vocabulary Server) and data format (ODV Ocean Data View).

Figure 3.7.1 shows the CDB entity-relationship diagram: all project data are stored in the *data_raw* table sequentially (Figure 3.7.2). Each record includes a value that corresponds to a certain physical parameter in the instant saved in the timestamp field. Moreover, this value corresponds to a sensor (*id_sensor*) installed in a specific point identified by the *Id_location* field. *Id_location* refers to the *locations* table (Figure 3.7.3) which reports all georeferencing points of interest (automatic and manual sampling points, ancillary data points, etc). *Id_sensor* relates to the *Sensors* table which includes the list of all the instruments used (Figure 3.7.4). *Id_parameter* and *id_unit* respectively identify the measurement parameter and the unit of measurement to which the value refers and are linked to the *parameters_label* (Figure 3.7.5) and *unit_label* (Figure 3.7.6) tables.

The records of these last two tables reflect the standardized parameters and units of measurement of the NERC vocabulary. A script manages interfacing between NERC server and the WQIS CDB through the reSTful protocol. This allows to guarantee the interoperability of the data.

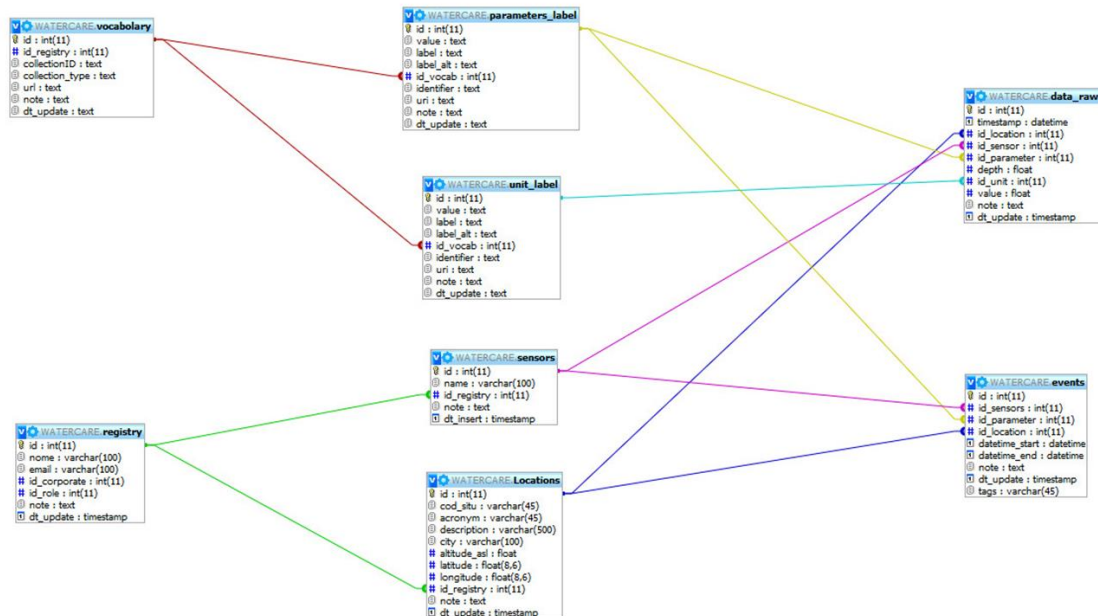


Figure 3.7.1. WQIS CDB Entity-relationship diagram: main tables and relationships.

id	timestamp	id_location	id_sensor	id_parameter	id_registry	depth	id_unit	value	note	dt_update
46636933	2021-09-14 16:00:00	20	10	102	20	NULL	12	0.5	NULL	2021-09-14 18:03:06
46636932	2021-09-14 16:00:00	20	10	101	20	NULL	12	-0.6	NULL	2021-09-14 18:03:06
46636931	2021-09-14 16:00:00	20	11	99	20	NULL	37	449...	NULL	2021-09-14 18:03:06
46636930	2021-09-14 16:00:00	20	11	100	20	NULL	32	194.61	NULL	2021-09-14 18:03:06
46636929	2021-09-14 16:00:00	20	11	64	20	NULL	16	8.1	NULL	2021-09-14 18:03:06
46636928	2021-09-14 16:00:00	20	13	88	20	NULL	35	-27.58	NULL	2021-09-14 18:03:06
46636927	2021-09-14 16:00:00	20	12	89	20	NULL	19	-3	NULL	2021-09-14 18:03:06
46636926	2021-09-14 16:00:00	20	10	85	20	NULL	34	0.00...	NULL	2021-09-14 18:03:06
46636925	2021-09-14 16:00:00	20	10	84	20	NULL	33	0.064	NULL	2021-09-14 18:03:06
46636924	2021-09-14 16:00:00	20	6	62	20	NULL	15	3	NULL	2021-09-14 18:03:06
46636923	2021-09-14 16:00:00	20	11	59	20	NULL	20	11.33	NULL	2021-09-14 18:03:06
46636922	2021-09-14 16:00:00	20	11	61	20	NULL	16	1.15	NULL	2021-09-14 18:03:06
46636921	2021-09-14 16:00:00	20	11	60	20	NULL	26	33.29	NULL	2021-09-14 18:03:06
46636920	2021-09-14 16:00:00	20	11	58	20	NULL	19	0	NULL	2021-09-14 18:03:06
46636919	2021-09-14 16:00:00	20	11	55	20	NULL	14	74.62	NULL	2021-09-14 18:03:06
46636918	2021-09-14 16:00:00	20	11	54	20	NULL	25	6.84	NULL	2021-09-14 18:03:06
46636917	2021-09-14 16:00:00	20	11	56	20	NULL	14	74.62	NULL	2021-09-14 18:03:06
46636916	2021-09-14 16:00:00	20	11	57	20	NULL	25	0	NULL	2021-09-14 18:03:06

Figure 3.7.2. Extract of data_raw table. For example, the first record refers to Pescara River station (id_location=20), the value 0.5 identifies the Tilt West North (id_parameter=102) measured in Degrees (id_unit=12) by the Weather Station Campbell sensor (id_sensor=10).

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id	cod_situ	acronym	description	city	altitude_asl	latitude	longitude	id_typology	id_registry	note	dt_update
9	SW100_1	NULL	Arzilla seawater 100m 1	1	0	43.853275	13.008783	2	2	NULL	2019-07-02 14:59:26
10	SW100_2	NULL	Arzilla seawater 100m 2	1	0	43.853394	13.009300	2	2	NULL	2019-07-02 14:59:26
11	SW100_3	NULL	Arzilla seawater 100m 3	1	0	43.853256	13.010021	2	2	NULL	2019-07-02 14:59:26
12	SW150_1	NULL	Arzilla seawater 150m 1	1	0	43.853622	13.008398	2	2	NULL	2019-07-02 14:59:26
13	SW150_2	NULL	Arzilla seawater 150m 2	1	0	43.853821	13.009211	2	2	NULL	2019-07-02 14:59:26
14	SW150_3	NULL	Arzilla seawater 150m 3	1	0	43.853619	13.010341	2	2	NULL	2019-07-02 14:59:26
15	SW200_1	NULL	Arzilla seawater 200m 1	1	0	43.854000	13.007997	2	2	NULL	2019-07-02 14:59:26
16	SW200_3	NULL	Arzilla seawater 200m 3	1	0	43.853939	13.010595	2	2	NULL	2019-07-02 14:59:26
17	SW0	NULL	Arzilla seawater 0m	1	0	43.852459	13.009341	2	2	NULL	2019-07-02 14:59:26
18	WATERCARE FA...	NULL	Arzilla Outfall	1	0	43.852077	13.008192	1	1	NULL	2019-08-26 12:28:42
19	WATERCARE FA...	NULL	Arzilla Upstream	1	NULL	43.852200	13.002062	1	1	NULL	2019-08-26 12:28:42
20	WATERCARE-PE...	NULL	Pescara Outfall	2	0	42.466816	14.223928	1	20	NULL	2019-09-06 15:11:40
21	URBFANO	NULL	Bollettino UNIURB	1	0	43.854721	13.029722	2	2	500...	2019-10-18 16:16:04
22	SW250_1	NULL	Arzilla seawater 250m 1	1	0	43.854343	13.007683	2	2	NULL	2019-10-23 14:03:55
23	SW250_3	NULL	Arzilla seawater 250m 3	1	0	43.854340	13.011015	2	2	NULL	2019-10-23 14:03:55
24	SWLD	NULL	Arzilla seawater Lido	1	0	43.852306	13.010802	2	2	NULL	2019-10-24 11:40:45
25	WATERCARE-P...	NULL	Pesca River ISCO	4	0	45.049271	14.050234	1	16	NULL	2020-02-19 14:38:29

Figure 3.7.3. Extract of Locations table. For example, record 18 corresponds to the Arzilla outfall station in Fano (city=1) with coordinates 43.852077, 13.008192. It is a sampling point on the river (id_typology=1; 1 is River, 2 is Sea) and the CNR-IRBIM is the site manager (id_registry=1).

id	name	id_registry	note	dt_insert
1	Floodway	7	NULL	2019-06-10 17:15:29
4	Rainfall Sensor 2636	5	NULL	2019-06-13 12:40:59
5	Level Sensor 1052	5	NULL	2019-06-13 12:59:02
6	Avalanche Sampler	1	NULL	2019-06-14 15:59:33
8	Manual Sampling	NULL	NULL	2019-09-06 09:59:37
9	Datalogger CR1000X	1	NULL	2019-10-07 17:23:32
10	Weather Station Campbell ATMOS-41	1	NULL	2019-10-07 17:23:33
11	YSI EXO2 Multiparameter Sonde	1	NULL	2019-10-07 17:24:48
12	Siemens Sitrans Probe LU240	1	NULL	2020-01-20 12:09:07
13	Liquids Pump Verderflex Dura7	1	NULL	2020-01-29 14:16:29
14	Relay power failure	1	NULL	2020-01-29 16:58:48

Figure 3.7.4. Extract of Sensors table.

id	value	label	label_alt	id_vocab	identifier	uri	note	dt_update
4	WSPD	HORIZONTAL WIND SPEED	WSPD	4	SDN:P09::WSPD	http://vocab.nerc.ac.uk/collection/P09/current/...		
5	WDIR	WIND DIRECTION REL. TRUE NORTH	WDIR	4	SDN:P09::WDIR	http://vocab.nerc.ac.uk/collection/P09/current/...		
6	CAPH	Air pressure	Air_Press	2	SDN:P02::CAPH	http://vocab.nerc.ac.uk/collection/P02/current/...		
7	TEMP	Temperature of the water column	WC_Temp	2	SDN:P02::TEMP	http://vocab.nerc.ac.uk/collection/P02/current/...		
8	CDTA	Air temperature	Air_temp	2	SDN:P02::CDTA	http://vocab.nerc.ac.uk/collection/P02/current/...		
9	PSAL	Salinity of the water column	WC_Sal	2	SDN:P02::PSAL	http://vocab.nerc.ac.uk/collection/P02/current/...		
10	CHUM	Atmospheric humidity	Humidity	2	SDN:P02::CHUM	http://vocab.nerc.ac.uk/collection/P02/current/...		
11	DBINAW01	Depth (spatial coordinate) of ADCP bin relative ...	BinDep_ADCPWaves	1	SDN:P01::DBINAW01	http://vocab.nerc.ac.uk/collection/P01/current/...		
12	DOXY	Dissolved oxygen parameters in the water column	WC_O2	2	SDN:P02::DOXY	http://vocab.nerc.ac.uk/collection/P02/current/...		
13	OPBSMAXX	Backscatter (520nm wavelength) in the water b...	OptBS	1	SDN:P01::OPBSMAXX	http://vocab.nerc.ac.uk/collection/P01/current/...		
14	OPBS	Optical backscatter	OptBS	2	SDN:P02::OPBS	http://vocab.nerc.ac.uk/collection/P02/current/...		
15	FVLTCDOM	Raw signal (voltage) of instrument output by in...	CDOM_Volt	1	SDN:P01::FVLTCDOM	http://vocab.nerc.ac.uk/collection/P01/current/...		
16	FLUO	FLUORESCENCE	FLUO	4	SDN:P09::FLUO	http://vocab.nerc.ac.uk/collection/P09/current/...		

Figure 3.7.5. Extract of parameters_label table. value, label, and label_alt is obtained from the NERC vocabulary. The identifier corresponds to the ID of the NERC collection and the URI contains the link to the vocabulary.

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id	value	label	label_alt	id_vocab	identifier	uri	note	dt_update
11	UVAA	Metres per second	m/s	3	SDN:P06::UVAA	http://vocab.nerc.ac.uk/collection/P06/current/...		
12	UAAA	Degrees	deg	3	SDN:P06::UAAA	http://vocab.nerc.ac.uk/collection/P06/current/...		
13	UPBB	Millibars	mBar	3	SDN:P06::UPBB	http://vocab.nerc.ac.uk/collection/P06/current/...		
14	UPCT	Percent	%	3	SDN:P06::UPCT	http://vocab.nerc.ac.uk/collection/P06/current/...		
15	UPAA	Degrees Celsius	degC	3	SDN:P06::UPAA	http://vocab.nerc.ac.uk/collection/P06/current/...		
16	UUUU	Dimensionless	Dmless	3	SDN:P06::UUUU	http://vocab.nerc.ac.uk/collection/P06/current/...		
17	UCML	Number per millilitre	#/ml	3	SDN:P06::UCML	http://vocab.nerc.ac.uk/collection/P06/current/...	NULL	NULL
18	UXMM	Millimetres	mm	3	SDN:P06::UXMM	http://vocab.nerc.ac.uk/collection/P06/current/...	NULL	NULL
19	ULAA	Metres	m	3	SDN:P06::ULAA	http://vocab.nerc.ac.uk/collection/P06/current/...	NULL	NULL
20	UULT	Volts	V	3	SDN:P06::UULT	http://vocab.nerc.ac.uk/collection/P06/current/...	NULL	NULL
21	ULKM	Kilometres	KM	3	SDN:P06::ULKM	http://vocab.nerc.ac.uk/collection/P06/current/...	NULL	NULL
22	MSCM	MilliSiemens per ce...	msS/cm	3	SDN:P06::MSCM	http://vocab.nerc.ac.uk/collection/P06/current/...	NULL	NULL
23	UPPT	Parts per thousand	ppt	3	SDN:P06::UPPT	http://vocab.nerc.ac.uk/collection/P06/current/...	NULL	NULL

Figure 3.7.6. Extract of units_label table. value, label and label_alt is obtained from the NERC vocabulary. The identifier corresponds to the ID of the NERC collection and the URI contains the link to the vocabulary.

3.7 WEB data presentation and sharing

The data acquired and collected according to the procedure explained in section 3.1, are analysed and visualized using Grafana (Grafana Labs, 2020) open-source software installed on a dedicated web server at the CNR-IRBIM (Figure 3.8.1).

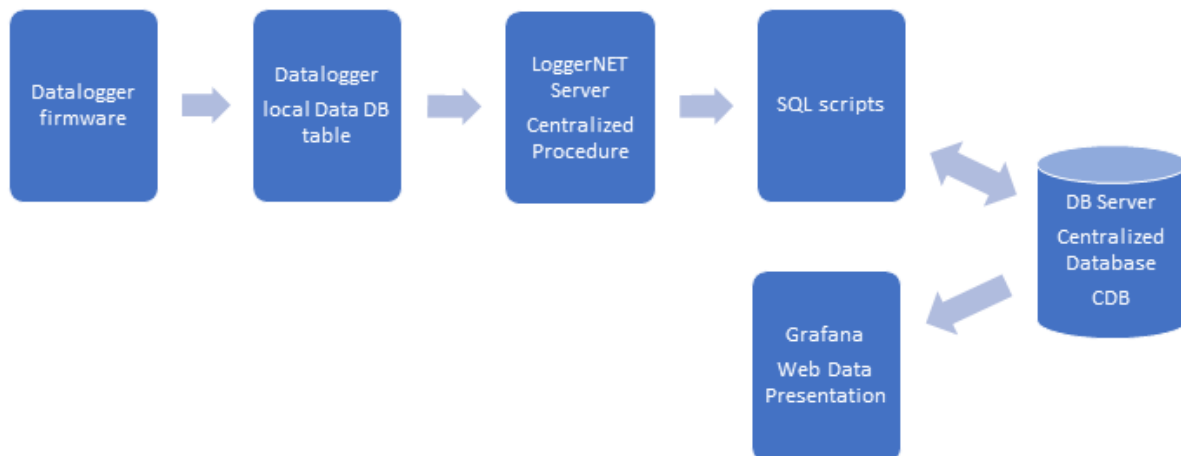


Figure 3.8.1. Block Diagram showing the procedure for acquiring, storing, and displaying data.

CNR IRBIM staff has developed a dashboard for each project site to display graphs and statistics of all parameters analysed (air, water, chemical, physical, and microbiological). The dashboard of each Watercare site is characterized by a set of panels (the basic data visualization building block). Each panel allows one or more physical parameters to be plotted and correlated versus time. Furthermore, through the Grafana web interface it is possible to access the site management pages detailed in paragraph 4.

The web interface is protected and accessible with the credentials that the CNR-IRBIM staff has provided to all partners. Once logged in, the user is redirected to the *Watercare Sites* homepage with a summary map of all the project sites (Figure 3.8.2). From the map the user can click on the markdown focused on the site of interest and then open the *Data visualization* link to open the dashboard with site data and information.

The *analysis points* panel shows a map with all the sampling points provided for the specific site. The points are georeferenced and are extracted from the database. The user can see the sample id by hovering the mouse over the point (Figure 3.8.3).

The panels are organized into the following sections:

- FOM - Forecast Operational Model
- Last Observation
- Air
- Water
- Automatic Sampling
- Samples Analysis
- Hardware

Each section can be activated or deactivated by clicking on the > symbol or on the section name.

FOM -Forecast Operational Model shows 3 maps (water temperature, salinity, and *E. coli* concentration of the next two-day forecast model (see section 3.9).

The *Last Observation* section (Figure 3.8.4) contains the air and water information from the latest update. Furthermore, it includes information of the ISCO sampler status. *Last Sample Sampling STATUS* reports the status of the sampler:

- *Ready to Sample* – the sampler is ready, and it is possible to start a sampling.
- *Sampling in Progress* – a sampling was started and is still in progress.

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- *Waiting for ACK Button* – the sampling is finished; the sampler has collected all the samples. The staff will have to replace the bottle carrier, carry out the required cleaning and then press the ACK button (see section 0).

Bottle shows the last sampled bottle. Sample Time and Sample Status reports respectively the timestamp of the last sample and the status (sample ok, sample in progress, liquid lost, etc.).

The *AIR* section (Figure 3.8.5) includes graph panels with weather information collected by the weather station installed on the monitoring site (data are updated every 30 minutes).

The graph panels inside the *WATER* section (Figure 3.8.6) show the measurements made by the CTD probe, water level and everything related to measurements in water. Data are updated every 30 minutes.

The *Automatic Sampling* section (Figure 3.8.7) includes graphs with real-time trend of the sampling status over time (data are updated every 1 minute).

The *Sample Analysis* section (Figure 3.8.8 - 3.8.9) reports the data generated by chemical and microbiological analysis derived from automatic or field sampling at sea (for example, coliform concentration). If provided, it also shows ancillary analysis data. Data is updated every 30 minutes.

The *Hardware* section (Figure 3.8.10 - 3.8.11) includes all important information to analyse the operating status of the systems installed on the monitoring site (data logger temperature and voltage, EXO voltage, ISCO sampler fridge temperature, etc). In the event of anomalies, the system sends an alert to all the technical managers as described in the deliverable 5.2.2

The data visualization site was updated at the beginning of 2021: Grafana was updated to the latest major release and the dashboards were upgraded with more attractive graphics, cool and easy to be consulted.



Figure 3.8.2. Watercare Sites Map.



Figure 3.8.3. Show the Fano Arzilla Outfall map with the sampling points.

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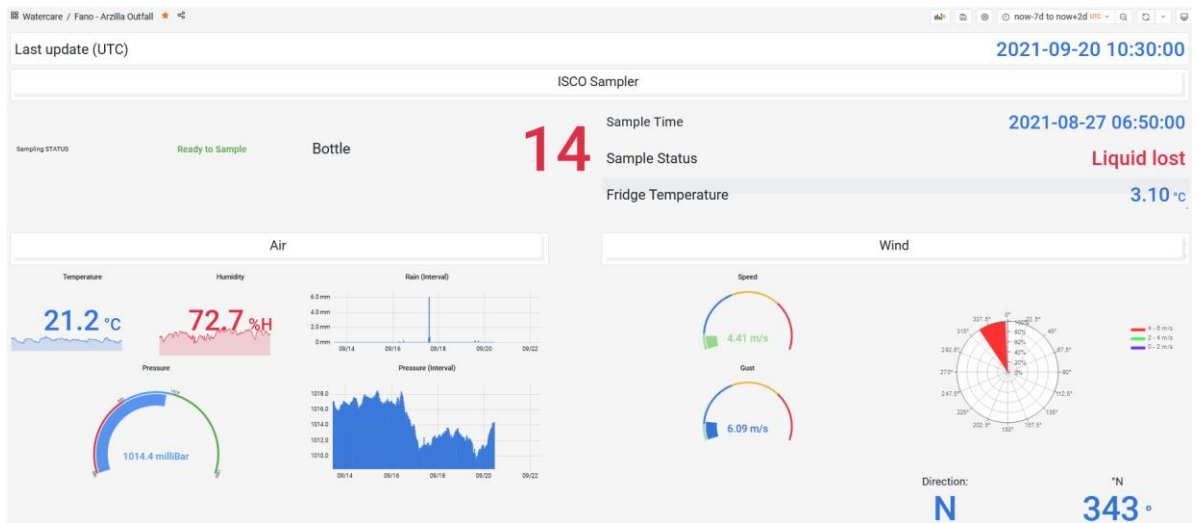
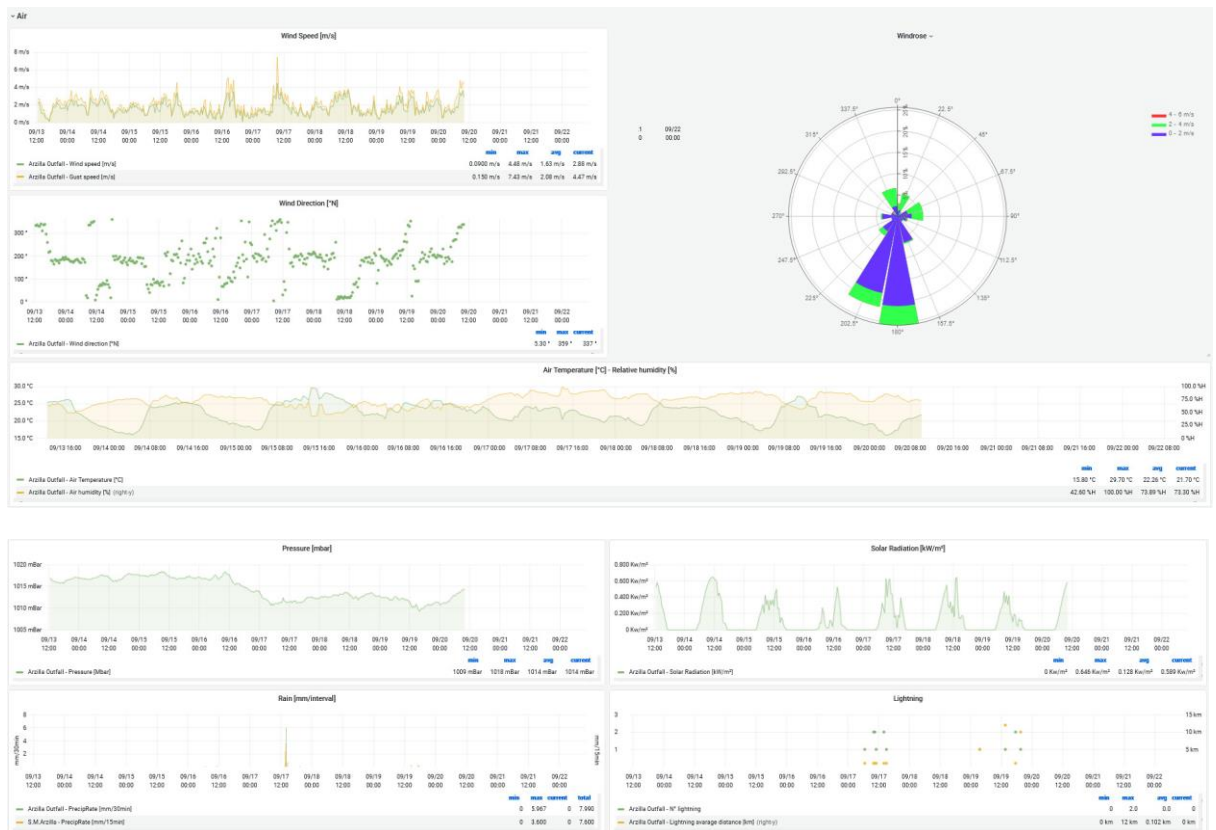


Figure 3.8.4. Example of field observation.



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Figure. 3.8.5. Example of the air section.



Figure 3.8.6. Example of the water section. The vertical blue lines indicate the time of river automatic sampling. They are shown in all graphs of the site dashboard.

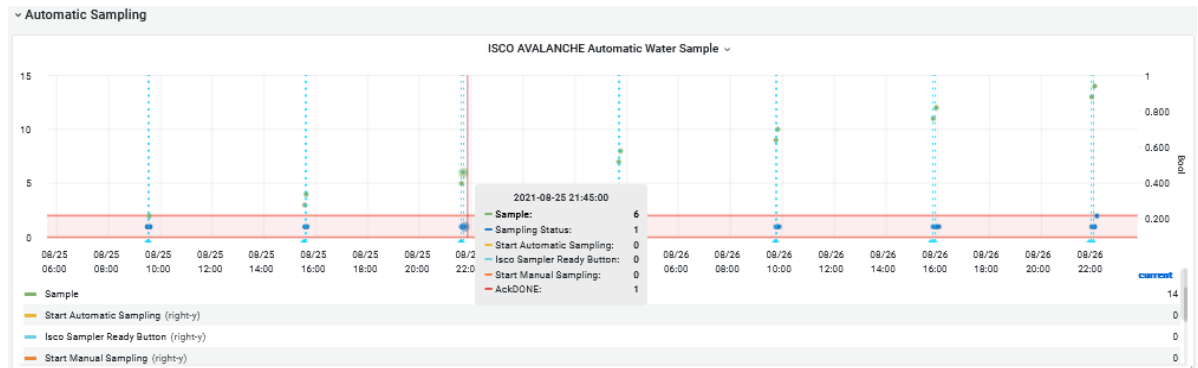


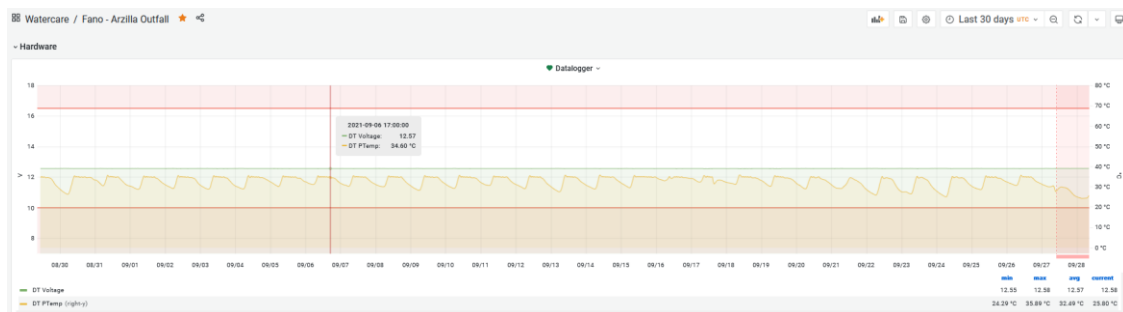
Figure 3.8.7. Automatic Sampling section.



Figure 3.8.8. Sample Analysis section, part 1.



Figure 3.8.9. Sample Analysis section, part 2.



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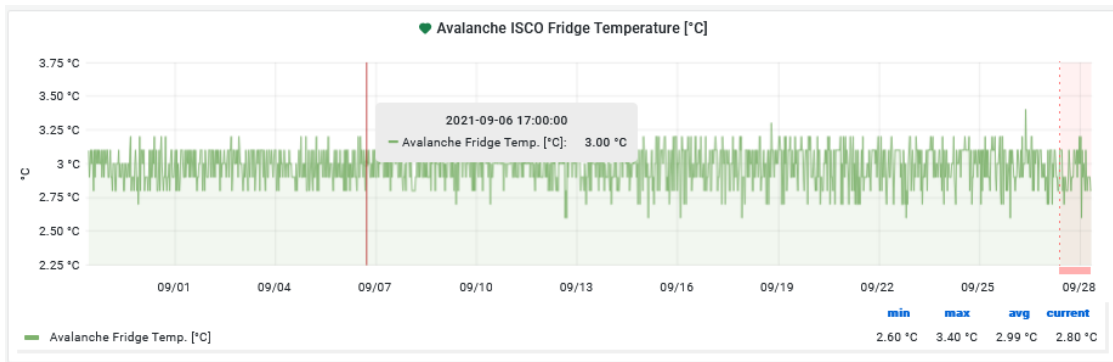
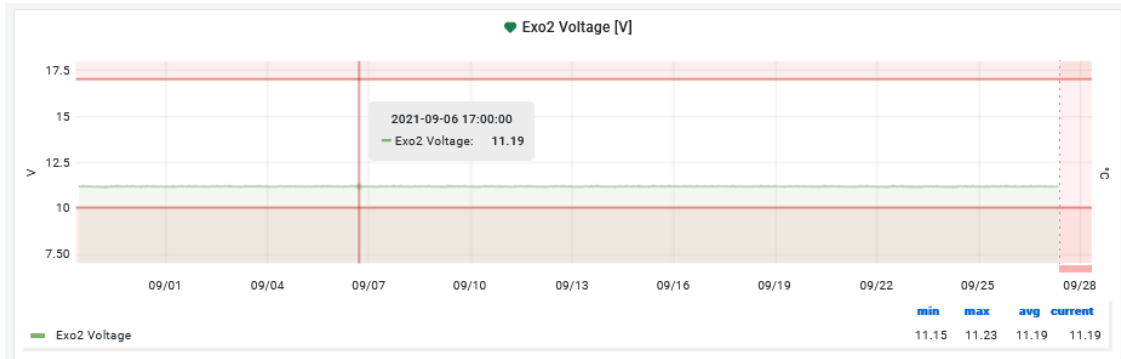
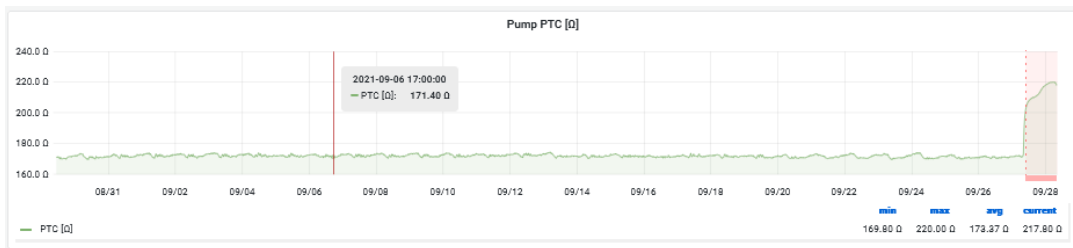
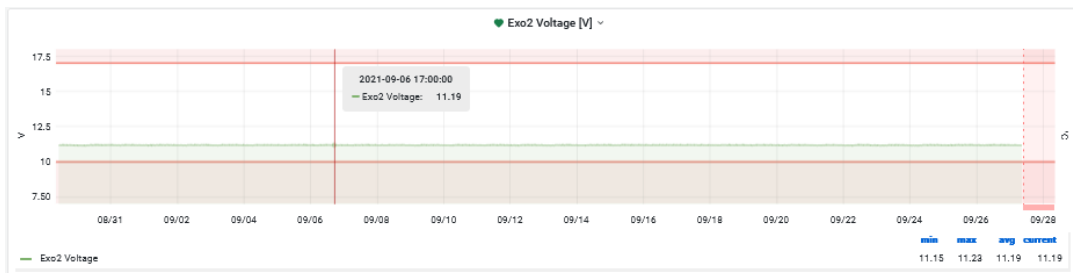


Figure 3.8.10. Hardware section, part 1.



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Figure 3.8.11. Hardware section, part 2.

3.8 Forecast Operational Model

A finite element hydrodynamic model was applied to five study areas in the Adriatic Sea, which differ for urban, oceanographic, and morphological conditions. With the help of transport-diffusion and microbial decay modules, the dispersal of *E. coli* concentration is simulated and forecasted (Ferrarin et al., 2021).

The modelling framework presented here is based on the System of HydroDynamic Finite Element Modules (SHYFEM, Umgiesser et al., 2014) code, an open-source unstructured ocean model for simulating hydrodynamics and transport processes at very high resolution. The modelling suite consists of:

- a 3D hydrodynamic model, that describes currents and mixing of water mass in the system;
- a transport and dispersion module, that simulates the dispersion of solute and microorganisms through the system;
- a microbial decay module, which defines the decay of microorganisms considering various environmental conditions.

The model runs in a full 3-D baroclinic mode with the water column discretized in zeta or hybrid (mixed sigma and zeta) layers with varying thickness (see the site-specific settings illustrated below). The discharge of the sewerage outlet is simulated with a Eulerian approach, where the concentration of *E. coli* is prescribed in outflow and the impact of the concentration is evaluated on the coast. The simulations are forced:

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- at the sea open boundary by sea temperature, salinity, water level and currents conditions obtained from the TIRESIAS operational system of the Adriatic Sea (Ferrarin et al., 2019). Such an unstructured oceanographic model reproduces in detail the general circulation in the Adriatic Sea, as well as several relevant coastal dynamics, like tidal amplification, saltwater intrusion, storm surge and riverine water dispersion;
- at the sea surface by meteorological data (air temperature, solar radiation, humidity, cloud cover, mean sea level pressure, wind speed and direction) from the high-resolution MOLOCH model (Davolio et al., 2015). The MOLOCH model is implemented with a horizontal grid spacing of 1.25 km, and with 60 atmospheric levels and 7 soil levels and provides the meteorological parameters at hourly frequency;
- at the river boundary by forecasted water discharge time series at the Fano pilot site and by climatological river discharge at the other study sites.;
- at the pollutant sources by bacteria concentration and water volume according to the available site-specific data.

In all study sites, the numerical domain considers the area of interest and a larger part of the coastal and shelf seas. To adequately resolve the river-sea continuum, the grids also include the lower part of the considered river (Fig. 3.8.12). The use of elements of variable sizes, typical of finite element methods, is fully exploited, in order to suit the complicated geometry of the coastal sites. The resolution of the triangular elements varies from 1-2 km in the open sea to a few meters near the river mouths and close to the beaches. The bathymetry interpolated onto the numerical grids was obtained by merging high-resolution site-specific datasets covering the area of interest with the composite EMODnet dataset (EMODnet Bathymetry Consortium, 2020) for the outer open sea.

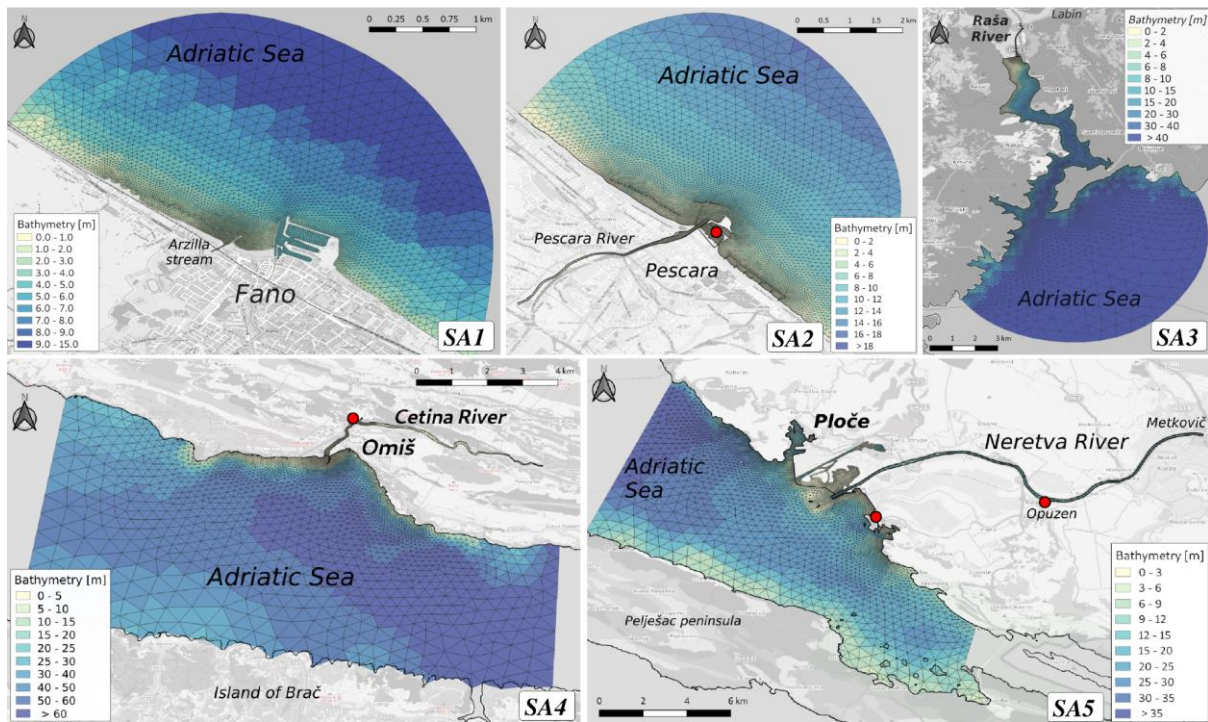


Figure 3.8.12. Numerical grids with the superimposed bathymetry of the five target areas.

Model results were evaluated against water level, sea temperature, salinity and *E. coli* concentrations acquired in situ, demonstrating the capacity of the modelling suite in simulating the circulation in the coastal areas of the Adriatic Sea, as well as main transport and diffusion dynamics, such as riverine and polluted waters dispersion.

The operational system chain (FOM) consists of a daily cycle of numerical integrations. Every day a two-day forecast is produced, with the initial conditions from a hot start based on the FOM forecast of the previous day. The system performs a 2 day-long simulation, and the results (water temperature, salinity and *E. coli* concentration) are shared through a THREDDS data server and integrated into the project's WEB system (Fig. 3.8.13).

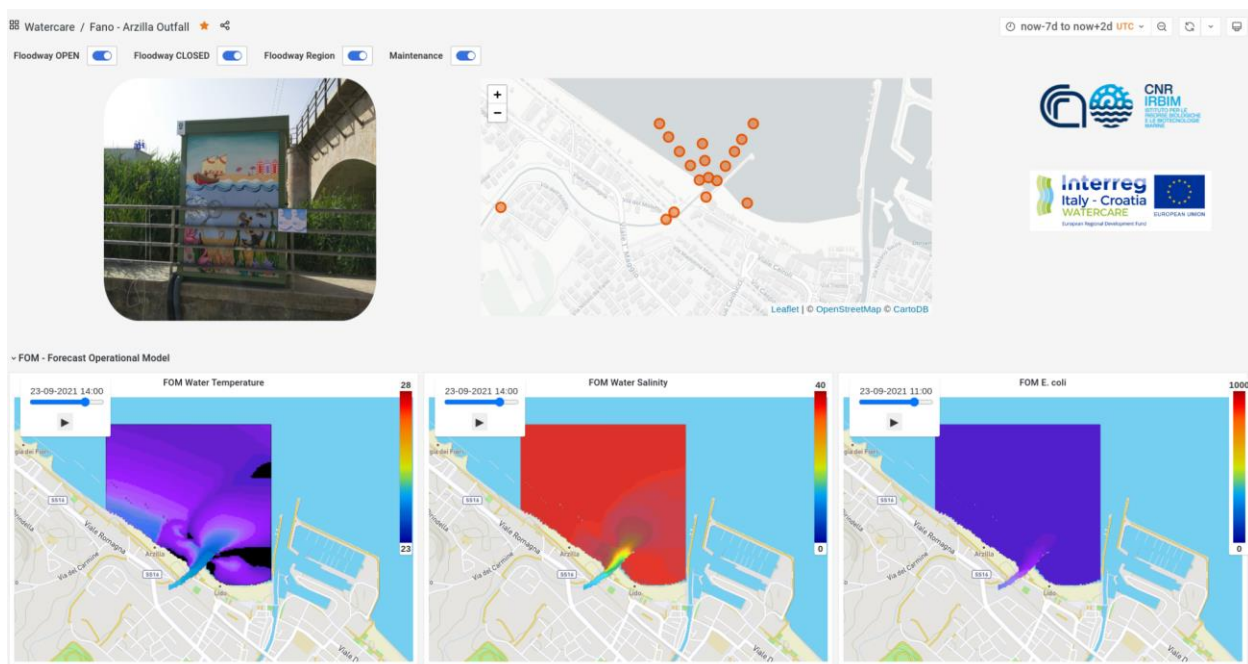


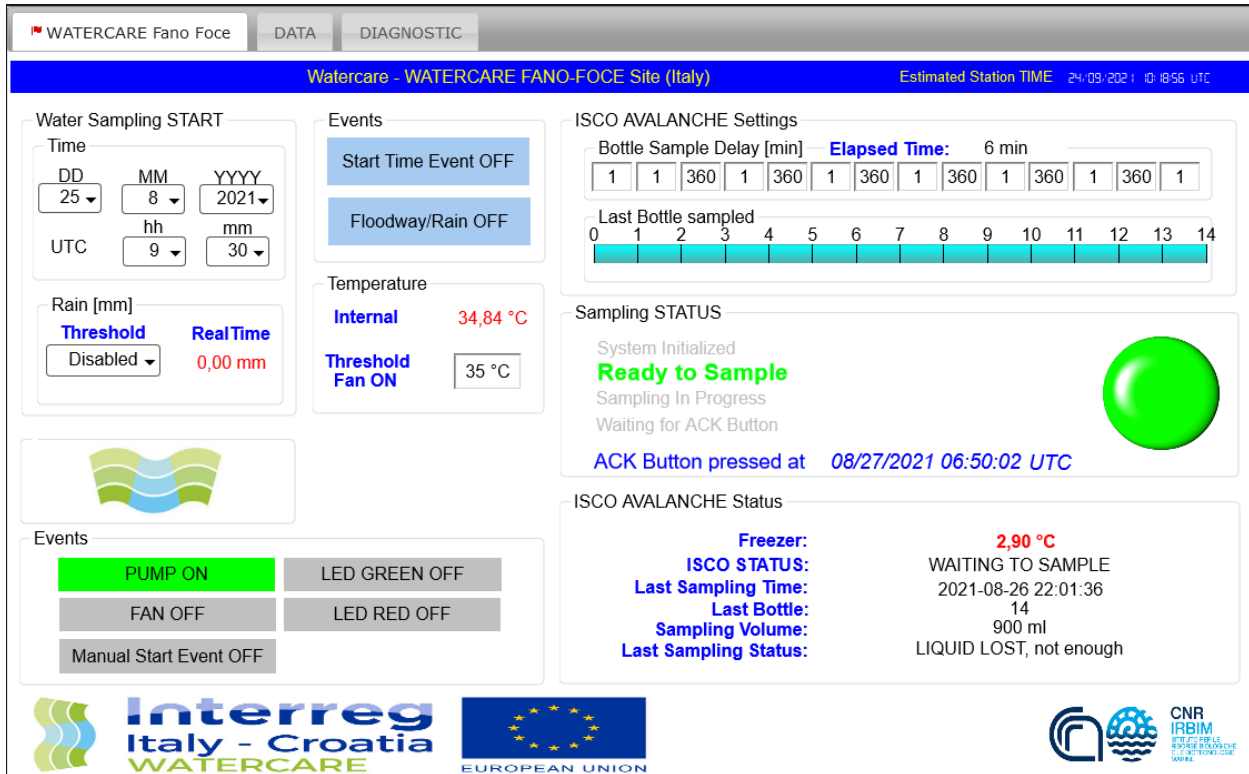
Figure 3.8.13. Example of visualization of the FOM at Fano pilot site in section 3.8 WEB data presentation and sharing.

3.9 Alert tool

The alert tool is detailed in the deliverable of the WP5 as follows:

- 5.2.1 – Simulations for the validation of the Alert Tool.
- 5.2.2 –Alert Tool final release.

4. SITE MANAGEMENT



The screenshot displays the 'WATERCARE Fano Foce' web interface. It features several key sections:

- Water Sampling START:** Includes a date and time selector (DD: 25, MM: 8, YYYY: 2021, UTC: 9:30).
- Events:** Contains buttons for 'Start Time Event OFF' and 'Floodway/Rain OFF'.
- Rain [mm]:** Shows a 'Threshold' set to 'Disabled' and 'Real Time' at '0,00 mm'.
- Temperature:** Displays 'Internal' temperature at '34,84 °C' and a 'Threshold Fan ON' at '35 °C'.
- ISCO AVALANCHE Settings:** Shows 'Bottle Sample Delay [min]' with a sequence of values (1, 1, 360, 1, 360, 1, 360, 1, 360, 1, 360, 1, 360, 1) and an 'Elapsed Time' of 6 min. A progress bar indicates 'Last Bottle sampled' at position 14.
- Sampling STATUS:** Shows 'System Initialized', 'Ready to Sample' (with a green indicator), 'Sampling In Progress', and 'Waiting for ACK Button'. The 'ACK Button pressed at' is '08/27/2021 06:50:02 UTC'.
- ISCO AVALANCHE Status:** Shows 'Freezer: 2,90 °C', 'ISCO STATUS: WAITING TO SAMPLE', 'Last Sampling Time: 2021-08-26 22:01:36', 'Last Bottle: 14', 'Sampling Volume: 900 ml', and 'Last Sampling Status: LIQUID LOST, not enough'.
- Events (Bottom):** Includes status indicators for 'PUMP ON' (green), 'LED GREEN OFF', 'FAN OFF', 'LED RED OFF', and 'Manual Start Event OFF'.

CNR Staff has developed a web interface for the remote management of automatic sampling.

This web tool has been designed to remotely activate the sampling cycle and to have a quick look at the events and the progress of the system. It is reserved to the Scientific site manager, a core actor of the WQIS system planned for each study site.

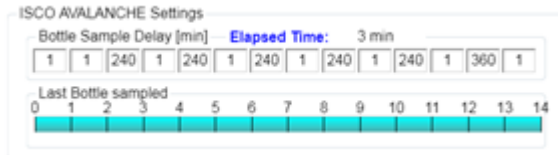
In collaboration with project staff, the Scientific Site Manager oversees consulting the WQIS and seeing the weather-marine forecasts. Then decides the strategy to be applied and is responsible for starting the sampling cycle. It also coordinates all logistic activities related to sample management.

The interface includes the following sections:

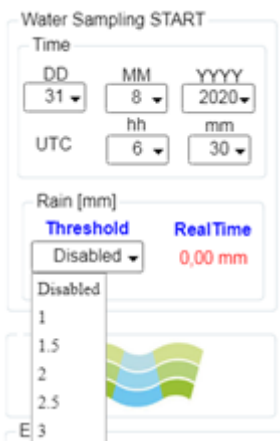
- **ISCO Avalanche settings** allows the programming and management of delay times (in minutes) between the bottle [n-1] and the bottle [n]. It includes a progress bar that indicates

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the last bottle sampled and Elapsed time indicates the minutes elapsed since sampling the last bottle.



- **Water Sampling start** allows the operator to set the automatic sampling start trigger. User can set a date and / or a minimum rain threshold.



- **Sampling Events** group box includes the Start Time Event and Floodway/Rain labels. Two labels turn green when a trigger event has occurred. For example, when the activation time has been reached or the rainfall threshold has been exceeded. The labels inside the Status Events group box indicate the status (ON green colour, OFF Gray colour) of the peristaltic pump, of the fan (if installed), and of the status LEDs located in the external panel of the electrical cabinet. There is the possibility to manually (and remotely) start the sampling cycle, using the keyboard of the ISCO AVALANCHE refrigerated automatic sampler. After manually starting the cycle, the data logger will manage the progress in any case, sending information to the WQIS DB.



- **Temperature** shows the current temperature of the data logger and probably the temperature reached inside the environment in which it is installed (consider that the temperature of the data logger is a little higher than the temperature outside it). In some of the Watercare sites cabinets there is a fan that is activated when the threshold set in *Threshold Fan ON* is exceeded. The main function is to lower the temperature inside the structure.



- **Sampling Status** reports the general progress of the automatic sampling cycle. *System initialized* is the initial start state of the data logger. In *Ready to sample state* the system is ready and waiting for a new sampling. Sampling in progress indicates that sampling is in progress. In the *Waiting for ACK Button* state, the automatic sampling is finished, the bottles are full waiting for the change by the operator. When the operator has pressed the button, the label *ACK Button pressed* at will appear and the UTC date and time will also be indicated. The site manager now knows that the bottles have been substituted, the water samples taken, and the system is ready for a new cycle.

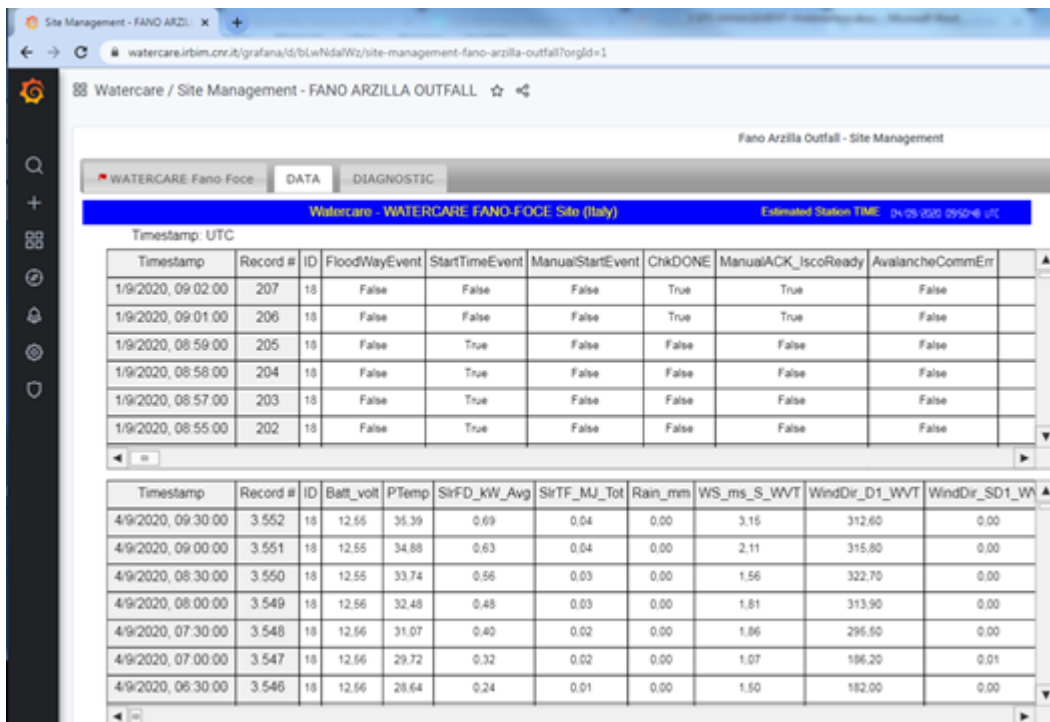


- **ISCO Avalanche Status** reports the status information of the ISCO AVALANCHE sampler. Freezer indicates the internal temperature of the freezer. This value is very important for the management of the water sample already taken. The WQIS continuously stores this value to certify the quality of the sample during the sampling cycle. ISCO STATUS shows the possible states returned by the sampler (WAITING TO SAMPLE, POWER FAILED, PUMP JAMMED, DISTRIBUTOR JAMMED, SAMPLER OFF, SAMPLE IN PROGRESS, INVALID COMMAND, CHECKSUM MISMATCH, INVALID BOTTLE, VOLUME OUT OF RANGE). *Last Sampling Time*, *Last Bottle*, *Sampling Volume* indicates the date and time (referred to the automatic sampler clock) of the peeled volume in the last bottle sampled. *Last Sampling STATUS* is the results of attempting the most recent sample (SAMPLE OK, NO LIQUID FOUND, LIQUID LOST, USER STOPPED, POWER FAILED, PUMP JAMMED, DISTRIBUTOR)

ISCO AVALANCHE Status

Freezer:	3,10 °C
ISCO STATUS:	WAITING TO SAMPLE
Last Sampling Time:	2020-09-01 08:54:24
Last Bottle:	14
Sampling Volume:	900 ml
Last Sampling Status:	SAMPLE OK

Site management interface also provides the DATA tab (Fig. 4.1) to view the real-time data of the general log table and the data generated by the sensors of the acquisition system such as weather data, the multiparameter probe, level sensor (if provided), etc. the DIAGNOSTIC tab (Fig. 4.2) shows a graph with the trend of datalogger temperature and battery voltage.



Watercare / Site Management - FANO ARZILLA OUTFALL

WATERCARE Fano Foce - DATA DIAGNOSTIC

Watercare - WATERCARE FANO FOCE Site (Italy) Estimated Station TIME: 04/09/2020 09:30:00 UTC

Timestamp: UTC

Timestamp	Record #	ID	FloodWayEvent	StartTimeEvent	ManualStartEvent	ChkDONE	ManualACK_IscoReady	AvalancheCommErr
1/9/2020, 09:02:00	207	18	False	False	False	True	True	False
1/9/2020, 09:01:00	206	18	False	False	False	True	True	False
1/9/2020, 08:59:00	205	18	False	True	False	False	False	False
1/9/2020, 08:58:00	204	18	False	True	False	False	False	False
1/9/2020, 08:57:00	203	18	False	True	False	False	False	False
1/9/2020, 08:55:00	202	18	False	True	False	False	False	False

Timestamp	Record #	ID	Batt_volt	PTemp	SirFD_kw_Avg	SirTF_MJ_Tot	Rain_mm	WS_ms_S_WVT	WindDir_D1_WVT	WindDir_SD1_WVT
4/9/2020, 09:30:00	3.552	18	12.55	35.39	0.69	0.04	0.00	3.15	312.60	0.00
4/9/2020, 09:00:00	3.551	18	12.55	34.88	0.63	0.04	0.00	2.11	315.80	0.00
4/9/2020, 08:30:00	3.550	18	12.55	33.74	0.56	0.03	0.00	1.56	322.70	0.00
4/9/2020, 08:00:00	3.549	18	12.56	32.48	0.48	0.03	0.00	1.81	313.90	0.00
4/9/2020, 07:30:00	3.548	18	12.56	31.07	0.40	0.02	0.00	1.86	296.50	0.00
4/9/2020, 07:00:00	3.547	18	12.56	29.72	0.32	0.02	0.00	1.07	196.20	0.01
4/9/2020, 06:30:00	3.546	18	12.56	28.64	0.24	0.01	0.00	1.50	182.00	0.00

Figure 4.1. Site Management. DATA tab.



Figure 4.2. Site Management. DIAGNOSTIC tab.

5. WQIS SAMPLING STRATEGY

The automatic activity is based on a real-time data acquisition system operating through an embedded system that consists of a data logger (Campbell Scientific CR1000X), a 4G communication system, a compact weather station (Campbell Scientific CLIMA VUE50), and a CTD multiparameter probe (YSI EXO2). A river-level ultrasound sensor (Siemens SITRANS LU240) is installed at the river mouth. A dedicated firmware is created to integrate the above systems. Data from these systems are collected at time intervals of 30 min and sent via the mobile network to the master station for storage in a dedicated database. The CTD (Conductivity, Temperature, Depth; Dissolved Oxygen; Turbidity) multiparameter probe is housed in a flow cell connected to a peristaltic pump. The pump is activated for 15 min before data reading to ensure adequate water flow and pipe cleanliness.

Automatic freshwater sampling for microbiological and chemical analyses is activated by a trigger event, e.g., heavy rain detected by the weather station, a rise in the river level, or CSO activation. Seawater sampling starts after CSO closure, its schedule adapted to weather and sea conditions. A time diagram showing the freshwater and seawater sampling phases is reported in the next Fig. 5.1.

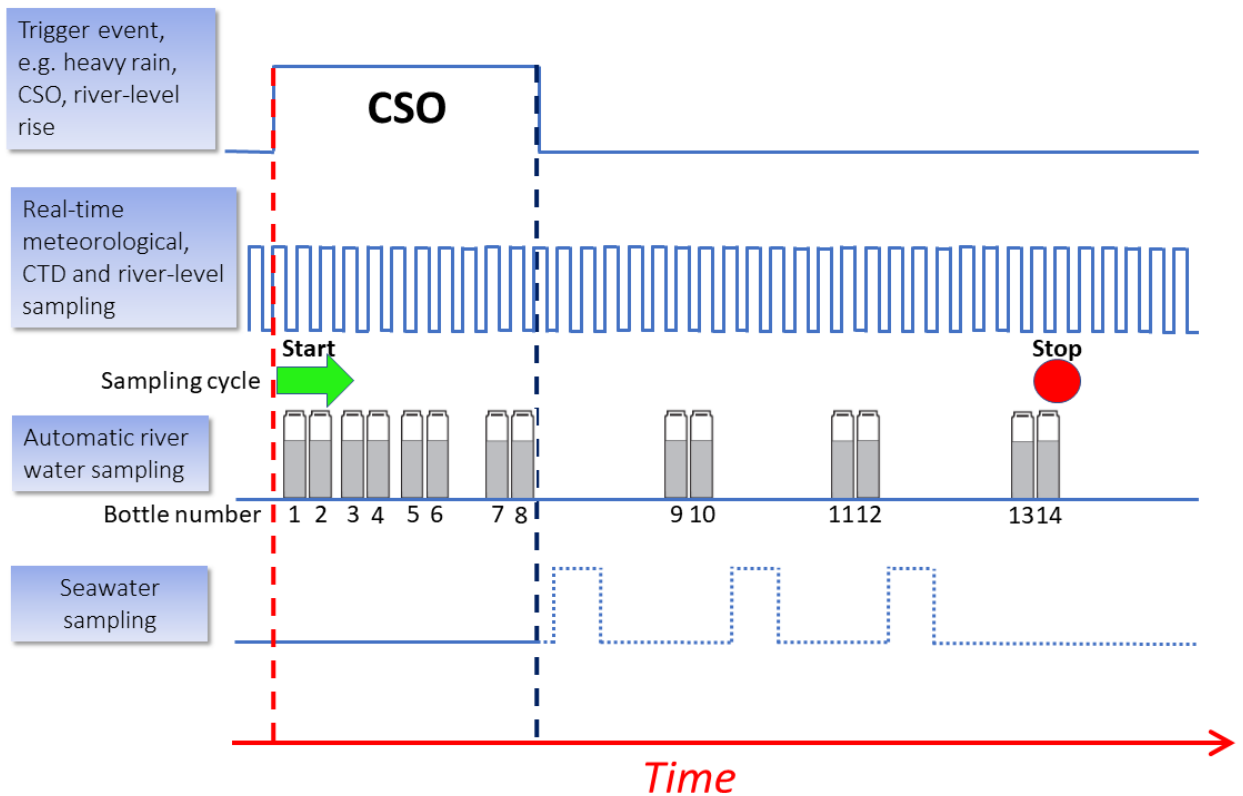


Figure 5.1. Time diagram (arbitrary scale) showing the water sampling phases activated by a Combined Sewer Overflows (CSO) event.

The autosampler, an ISCO Avalanche 6712 which provides for sample refrigeration, contains 14 bottles (capacity, 950 ml). The advantage of using this apparatus is that the sampling time scale can be set up remotely by the scientific site manager and adapted to the intensity of the meteorological event.

Upon system activation by the trigger event, the data logger sends a command to the two autosamplers to collect the freshwater samples and place them into bottle n and bottle $n + 1$. The water in bottle n is used for chemical-physical analysis whereas the content of bottle $n + 1$ is used for microbiological analysis. The samples are kept at 3–4 °C throughout the sampling cycle. At the end of the cycle the bottles are capped and replaced with new sterilized bottles for the next automatic sampling. All phases are monitored by the real-time data acquisition system, which reports any abnormalities via the alert tool (see Deliverables 5.1 and 5.2).

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ANNEX 1 - List of WQIS equipment

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the authors.

Ref	Image	Description	Station
1		<p>Datalogger Campbell Scientific CR1000X and Router LTE (Inhand IR915L or Teltonika)</p> <p>The CR1000X is a low-powered device designed to measure sensors, drive direct communication and telecommunications, analyze data, control external devices, and store data and programs in on-board, non-volatile storage. The electronics are RF-shielded and glitch-protected by a unique sealed, stainless-steel canister. A battery-backed clock assures accurate timekeeping. The on-board, BASIC-like programming language—common to all Campbell Scientific data loggers—supports data processing and analysis routines. The CR1000X wiring panel includes two switchable 12 V terminals, analog grounds dispersed among 16 analog terminals, and unpluggable terminal blocks for quick deployment. The router allows access to the datalogger remotely and connects it with the loggernet server.</p>	<p>Fano Arzilla Outfall</p> <p>Fano Arzilla Upstream</p> <p>Pola Rasa River</p> <p>Dubrovnik Neretva River</p> <p>Split Cetina Main</p> <p>Split Cetina Outfall</p> <p>Pescara Pescara River</p>

2		<p>YSI EXO2/EXO3 Multiparameter Sonde</p> <p>EXO2 is a Multiparameter Water Quality Sonde with 7 sensor ports (4 ports for the EXO3 version). It includes a central wiper and battery compartment.</p> <p>EXO is an extremely versatile instrument for unattended monitoring, allowing the user to automatically configure a sonde with different sensors for different applications. The smart sensors installed are Conductivity/Temperature, Dissolved Oxygen, pH & ORP, Salinity and Turbidity.</p> <p>The EXO communicates with the datalogger via SDI-12 protocol.</p> <p>https://www.y.si.com/exo2</p>	<p>Fano Arzilla Outfall</p> <p>Fano Arzilla Upstream</p> <p>Pola Rasa River</p> <p>Dubrovnik Neretva River</p> <p>Split Cetina Main</p> <p>Pescara Pescara River</p>
3		<p>Teledyne ISCO Avalanche Water Sampler</p> <p>ISCO Avalanche is a multifunction refrigerated sampler with the function of automatically sampling up to 14 bottles. it can be controlled locally using the commands and the local display or remotely via datalogger (the communication between the two devices is via RS232 serial protocol).</p> <p>https://www.teledyneisco.com/en-us/water-and-wastewater/avalanche</p>	<p>Fano Arzilla Outfall</p> <p>Fano Arzilla Upstream</p> <p>Pola Rasa River</p> <p>Dubrovnik Neretva River</p> <p>Split Cetina Main</p> <p>Split Cetina Outfall</p> <p>Pescara Pescara River</p>

4		<p>Campbell Scientific ClimaVUE50</p> <p>The ClimaVUE™50 is an all-in-one meteorological sensor. This sensor uses SDI-12 to report air temperature, relative humidity, vapor pressure, baro-metric pressure, wind (speed, gust, and direction), solar radiation, precipitation, and lightning strike (count and distance).</p> <p>https://www.campbellsci.com/climavue-50</p>	<p>Fano Arzilla Outfall</p> <p>Pola Rasa River</p> <p>Dubrovnik Neretva River</p> <p>Split Cetina Main</p> <p>Pescara Pescara River</p>
5		<p>Verdeflex Dura 7 peristaltic pump</p> <p>Verdeflex Dura 7 is a compact and high pressure peristaltic pump used for pumping water from the river to the flow cell for water analysis via EXO2/EXO3. The pump is powered in three-phase 380V through a 220V-380V inverter controlled by the datalogger (it manages the switching on and off of the pump). The datalogger checks the pump temperature by analyzing the resistance across a PTC installed in the pump motor.</p> <p>https://verdeflex.com/it/pompe-peristaltiche-industriali/verdeflex-dura</p>	<p>Fano Arzilla Outfall</p> <p>Fano Arzilla upstream</p> <p>Pescara Pescara River</p>
6		<p>Siemens Probe LU240 ultrasonic level transmitter</p> <p>Siemens LU240 is a compact level sensor for river level measurement. The transducer converts the level into a current (current loop 4-20mA) which is then read by the datalogger and converted into a value in meters.</p>	<p>Fano Arzilla Outfall</p>

		https://new.siemens.com/global/en/products/automation/process-instrumentation/level-measurement/continuous/ultrasonic/si-trans-probe-lu240.html	
7		<p>Campbell Scientific LR4 relay module</p> <p>LR4 is a relay module with 4 relays that mechanically latches the relay's state, allowing power to be removed. The only way to change the state of a relay is to send a command to the LR4 or to press the manual toggle button. The datalogger sends commands to the LR4 via the SDI-12 protocol or ModBus protocol.</p> <p>This module is used to control the peristaltic pump and cabinet air extractor. It also controls a signaling led strip.</p> <p>https://www.campbellsci.com/lr4</p>	<p>Fano Arzilla Outfall</p> <p>Fano Arzilla Upstream</p> <p>Pescara Pescara River</p>

ANNEX 2 - Equipment connection schema

