Project: “Monitoring Sea-water intrusion in coastal aquifers and Testing pilot projects for its mitigation” Interreg CBC Italy-Croatia 2014.-2020.

Priority Axis: Safety and resilience

Specific objective: Improve the climate change monitoring and planning of adaptation measures tackling specific effects, in the cooperation area

(D_3.1.7) Plan of the groundwater and surficial water monitoring networks of the Croatian site

Work Package 3: Studying

Activity 1: Sites characterization

Partner in charge: PP4 (UNIST-FGAG)

Partners involved: PP4 (UNIST-FGAG), PP5 (CROATIAN WATERS), PP6 (DUNEA)

Final version

Public report

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Contents

Aims and scopes

The plan is made to define the content of the monitoring activities to be done on Croatian project site river Neretva delta as an activity proposed by the project: “Monitoring Sea-water intrusion in coastal aquifers and Testing pilot projects for its mitigation” Interreg CBC Italy-Croatia 2014.-2020.

With a general idea to capture for salt water transient nature within the project area, plan defines in details future steps as: i) partial upgrade of existing monitoring system and ii) implementation of novel monitoring activities. Under the update of existing monitoring system, it is assumed present infrastructure like piezometers, photovoltaic cells, data transmitter stations and existing multi-parameter gauges will be kept. Exiting infrastructure will be updated with in total seven gauges and installed within river Neretva delta to enable continuous monitoring of parameters: i) ground water and/or surface water piezometric head, ii) temperature and iii) electrical conductivity. These data sets will be accessible to local farmers, public authorities and stakeholders via MoST mobile and web application. Link to access the application and to install it can be reached via: https://neretva.gradst.hr/dashboard (Figure 1).

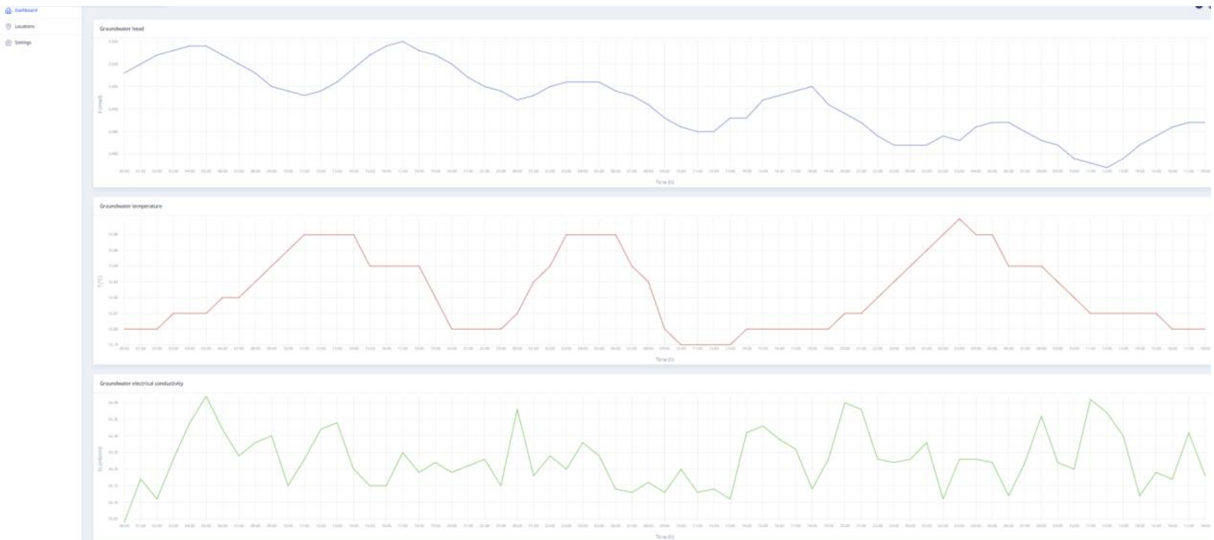

Figure 1 MoST web App screenshot

As a part of monitoring activities, an implementation of novel activities has been planned as well. Hereby, one assumes sampling of the ground water and surface water for purpose of laboratory analysis of the samples as taken from the area of interest at Croatian site.

Preparation work

Prior the definition of future monitoring system activities and related parameters, a detailed inspection of existing monitoring system and present ground and surface water features has been examined. Detailed inspection has been done by: i) existing gauges testing, ii) piezometers have been washed out and tested for functionality, iii) ground and surface water profiling.

Testing present multi parameter probes (Figure 2) enabled the insight of probes capacity and dynamic features of piezometric heads, electrical conductivity and temperature within the area of interest over the hydrological year (Figure 3).

Figure 2 Checking existing gauges at Neretva site

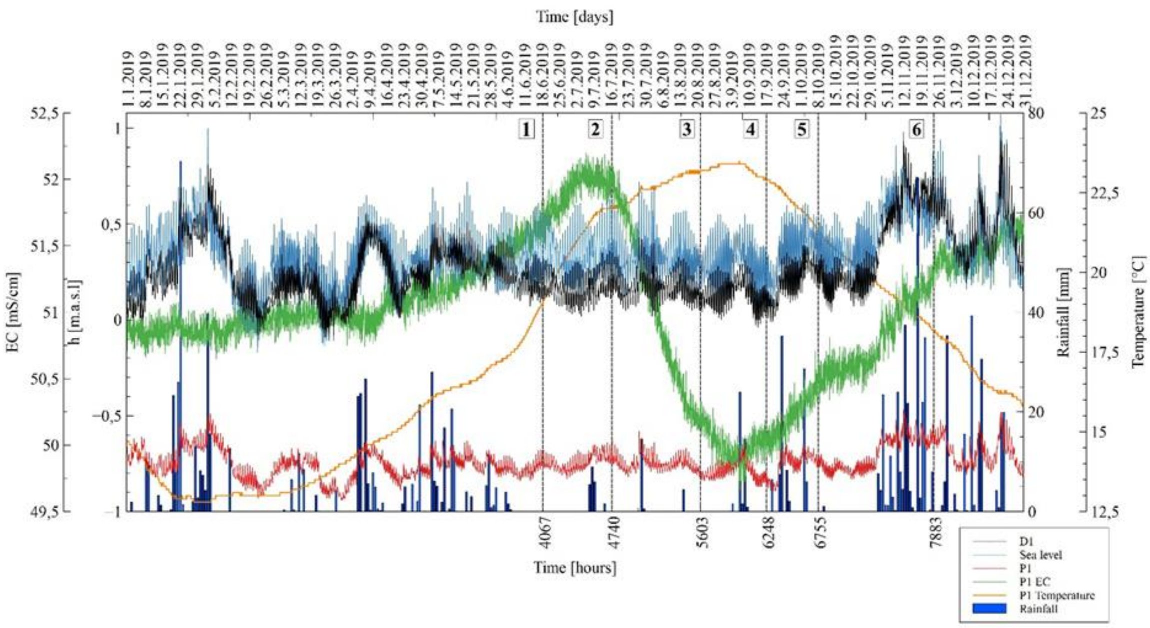

Figure 3 Plot of variables taken by existing monitoring system for 2019 year

Figure 4 Existing piezometers tested for functionality at Neretva site

Piezometers cleaning and washing out of suspended materials have been done during the May 2020. (Figure 4). In this way, the piezometer chasing has been ensured to enable inflow and outflow so future installed probes would show real aquifer state.

Ground and surface water profiling offered typical values of temperature and electrical conductivity (Figure 5). Together with piezometric heads it enabled the definition of vertical position of the probes which are a part of monitoring system upgrade (Figure 6 and Figure 7).

Figure 5 SEBA multi parameter gauge used for pro filing conductance at Neretva site

Finally, to ensure proper sampling of 500 ml of the water taken from the site, needed to conduct laboratory experiments and testing special sampler has been selected to be used (Figure 8). The latter has a diameter appropriate to be used for 2 inches' piezometer chasing diameter.

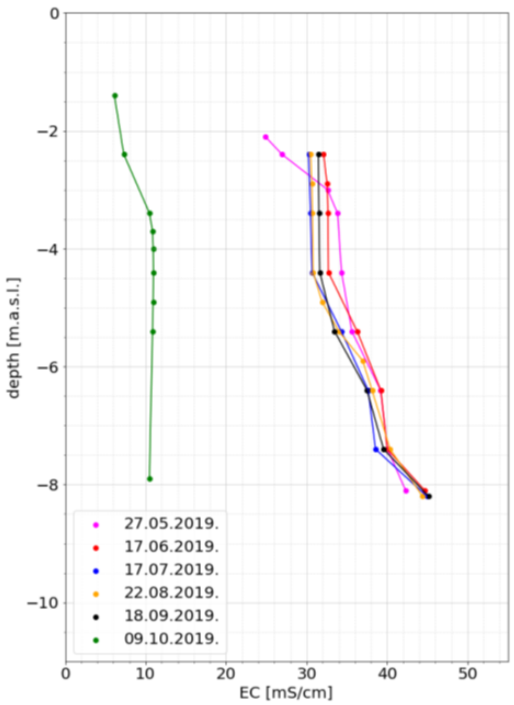

Figure 6 Electrical conductivity profiling results as taken at Neretva site during 2019.

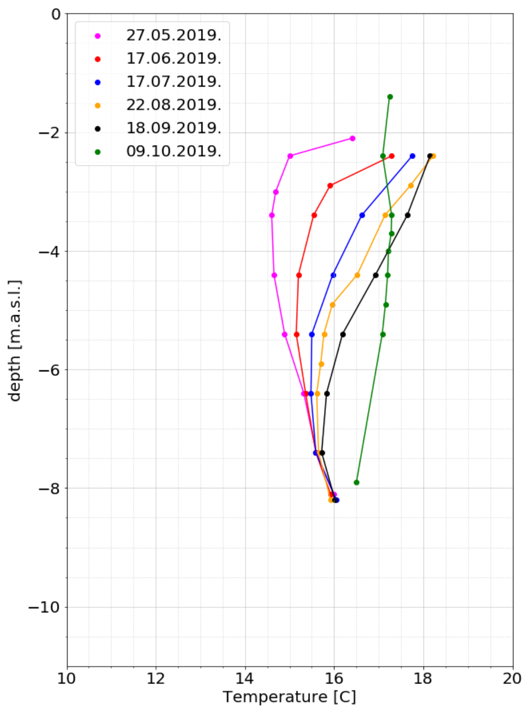

Figure 7 Electrical conductivity profiling results as taken at Neretva site during 2019.

Figure 8 Setup for water sampling

Real time monitoring of surface and ground water

At the area of interest there are in total seven piezometers installed and fully either partially equipped with necessary equipment (gauges, photovoltaic cells, data transmitter stations). At the locations (Figure 9) identified by:

- GW_MON_P1
- GW_MON_D1
- GW_MON_P2
- GW_MON_D2
- GW_MON_P4
- GW_MON_D4

there are pairs of deep and shallow piezometers installed. Shallow piezometers have been installed to penetrate strictly to the first geological layer from the ground surface (unconfined aquifer) and have been perforated in its full length as shown in Figure 10. This way of perforating well enables to get information on water column profile of measured variables either enables continuous multilevel time series.

At the location identified by GW_MON_D4 there is only a deep piezometer installed. In total four deep piezometers:

- GW_MON_D1
- GW_MON_D2
- GW_MON_D3
- GW_MON_D4

have been installed within the area of interest to be used to equip with appropriate probes. Above explained sets of piezometers will be used to install new gauges and/or probes to establish a reliable and continuous monitoring of the variables:

- piezometric head;
- electrical conductivity and
- temperature.

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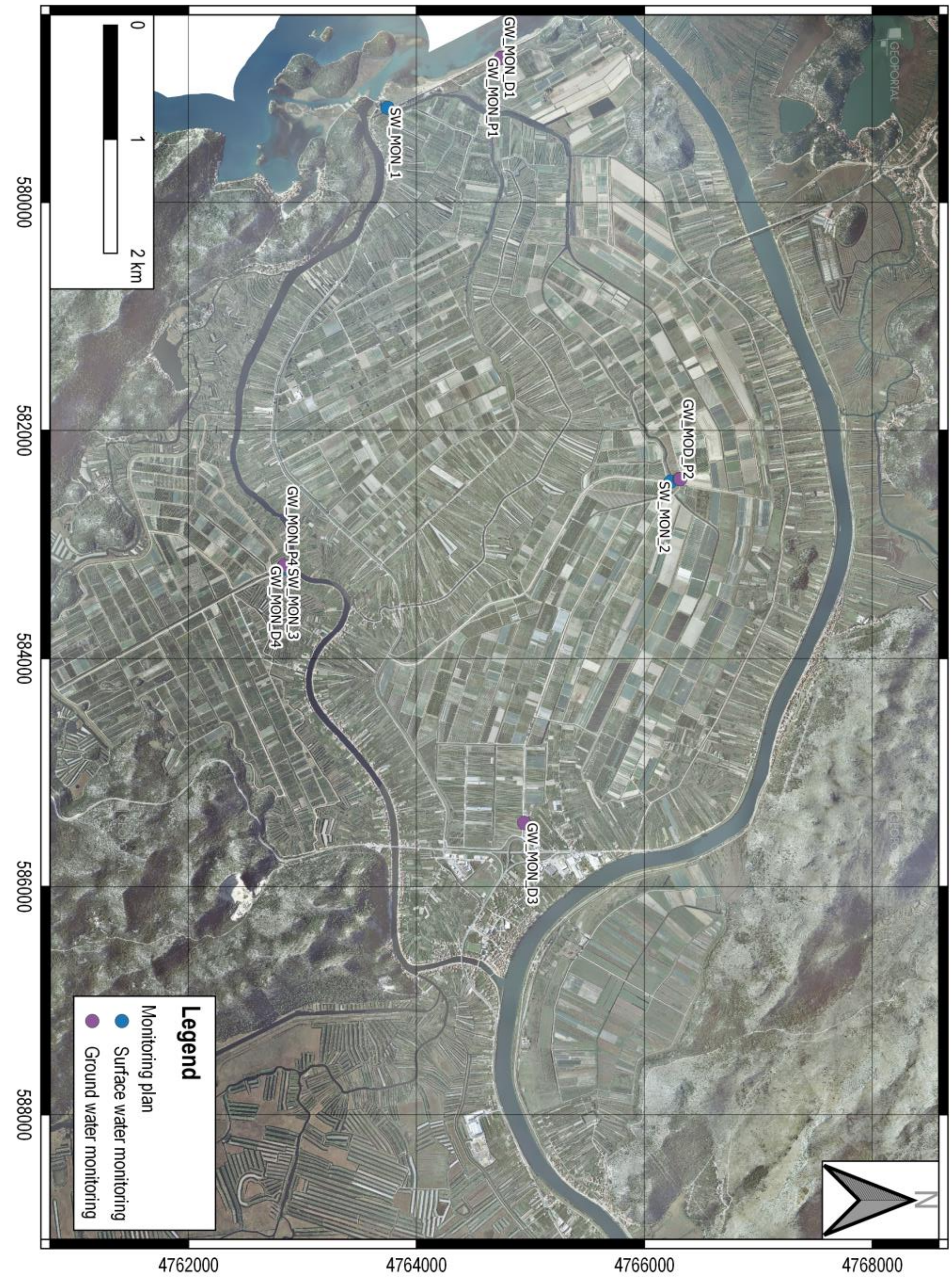

Figure 9 Geographic locations of real time monitoring system

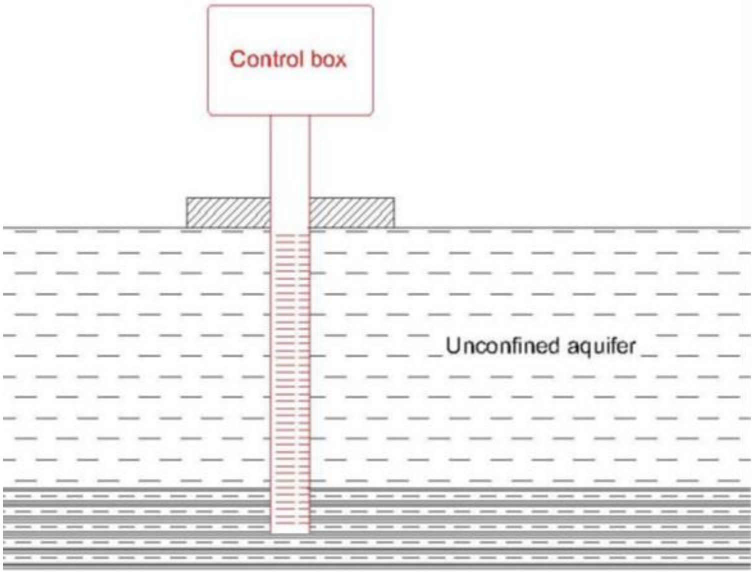

Figure 10 Characteristic cross section of shallow piezometers

Monitoring of the surface water is planned to be done at three locations (Figure 9) identified by:

- SW_MON_1
- SW_MON_2
- SW_MON_3.

Table 1 Coordinates of real time monitoring system locations

Monitoring ID	E (HTRS96)	N (HTRS96)
SW_MON_1	579170.22	4763745.37
SW_MON_2	582447.30	4766230.38
SW_MON_3	583209.04	4762848.42
GW_MON_D1	578730.73	4764746.96
GW_MON_P1	578734.06	4764741.97
GW_MOD_D2	582426.39	4766311.53
GW_MOD_P2	582426.39	4766314.44
GW_MON_D3	585440.40	4764946.99
GW_MON_D4	583187.74	4762837.62
GW_MON_P4	583185.97	4762842.09

Monitoring of the surface water is planned to be done by installing appropriate probes to main channels which are used to fed pumping stations with water from irrigation channels.

Details on monitoring locations has been shown in Table 1, where coordinates are expressed in HTRS96 coordinate system.

Below, each location covered by monitoring system is shown in details, enabling the insight to every location peculiarity. Figure 11, Figure 12 and Figure 13 show location at the western border of the study area, 80 m away from the sea where in total four piezometers have been installed, from whom two are in use, one penetrating unconfined aquifer and second one penetrating confining layer. Those piezometers are identified in Figure 9 as GD_MON_P1 (unconfined) and GW_MON_D1 (confined).

Figure 14 and Figure 15 show location in the middle of the study area, 1200 m away from the river Neretva where in total four piezometers have been installed, from whom two are in use, one penetrating unconfined aquifer and second one penetrating confining layer. Those piezometers are identified in Figure 9 as GD_MON_P2 (unconfined) and GW_MON_D2 (confined).

Figure 16 and Figure 17 show location at the eastern part of the study area, 600 m away from the river Neretva where in total two piezometers have been installed, from whom only one in use, penetrating confining layer. The latter has been identified in Figure 9 as GW_MON_D3 (confined).

Finally, Figure 18 shows location in the study area, near the river Mala Neretva where in total four piezometers have been installed, from whom two are in use, one penetrating unconfined aquifer and second one penetrating confining layer. Those piezometers are identified in Figure 9 as GD_MON_P4 (unconfined) and GW_MON_D4 (confined).

Figure 11 Monitoring location GW_MON_P1 and GW_MON_D1

Figure 12 Monitoring location GW_MON_P1 and GW_MON_D1

Figure 13 Monitoring location GW_MON_P1 and GW_MON_D1

Figure 14 Monitoring location GW_MON_P2 and GW_MON_D2

Figure 15 Monitoring location GW_MON_P2 and GW_MON_D2

Figure 16 Monitoring location GW_MON_D3

Figure 17 Monitoring location GW_MON_D3

Figure 18 Monitoring location GW_MON_P4 and GW_MON_D4

To capture for complete and continuous information on surface water quality state, three locations have been selected, respectively:

- SW_MON_1
- SW_MON_2
- SW_MON_3

Location of SW_MON_1 monitoring point is located at the existing inflow basin of pumping station Modrič (Figure 19 to Figure 21) in the south western part of the study area as shown in Figure 9. The location has been picked since most of surface water from area Jasenska, Opuzen ušće and Crepina ends up here. Within the basin necessary infrastructure has to be implemented to enable the installation of the probe to measure for head elevation, electrical conductivity and temperature.

SW_MON_2 monitoring point is located 1200 m away from the river Neretva, very close to piezometers identified by GW_MON_P2 and GW_MON_D2. Specifications of micro location where novel monitoring location for surface water is to be installed are shown in Figure 22 and Figure 23

Figure 24, Figure 25 and Figure 26 show location of the surface water monitoring location identified by SW_MON_3. Micro location is defined as the inlet basin for pumping station Prag thus collecting water from whole Vidrice area (southern part of the domain).

Figure 19 Monitoring location SW_MON_1

Figure 20 Monitoring location SW_MON_1

Figure 21 Monitoring location SW_MON_1

Figure 22 Monitoring location SW_MON_2

Figure 23 Monitoring location SW_MON_2

Figure 24 Monitoring location SW_MON_3

Figure 25 Monitoring location SW_MON_3

Figure 26 Monitoring location SW_MON_3

Real time monitoring of surface and ground water parameters

To define final parameters of the monitoring system, several additional checks and inspections have been done. From 30 April to 4 May 2019, a four-day dataset was performed with 5 minutes sampling time to conduct the convergence test of the sampling and averaging time analysis and its influence upon major piezometric head signal parameters tidal efficiency (TE) and temporal delay (ΔT). Firstly, sea level was used as observed with a 5 min sampling scale, whereas piezometric head sampling time was variable (5, 10, 15, 30, and 60 min). Secondly, sea level was used as defined on a 60 min sampling scale, whereas piezometric head sampling time was variable (5, 10, 15, 30, and 60 min). Independently of the sea level signal sampling time, tidal efficiency showed less than 0.4% relative difference, even when 60 min sampling time was used. Apart from TE, ΔT was found to be more sensitive to sampling time. Figure 27 implies a 10 min sampling time to reduce relative difference in ΔT below 2%, with hourly sampling time relative error equal to 10% for D1, whereas D2 and D4 showed a satisfactory difference (below 3%). If, instead of sampling time, an averaging time was analyzed, it was demonstrated that the obtained difference is double the one obtained for the equivalent sampling time.

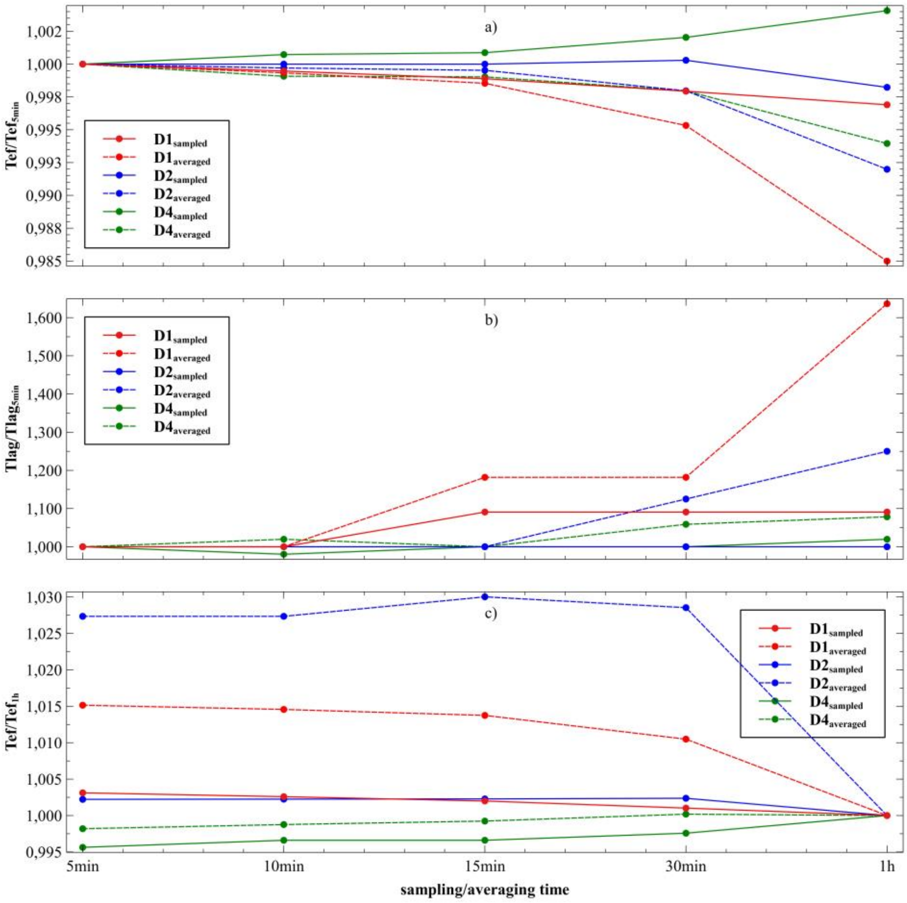

Figure 27 Parameters of monitoring probes selection

Plan of ground and surface water samplings

To support real time monitoring data series with additional data in order to enable the understanding of processes influencing salt water dynamic nature in total 124 water samples will be taken from study area within one hydrological year. These samples, once taken in situ, will be transported to laboratory to conduct laboratory analysis. Following Figure 28 in total 31 locations has been selected for water sampling, 24 of them representing surface water samples and 7 of them representing ground water samples. Groundwater samples are planned to be taken by existing piezometers, while surface water will be taken directly from surface channels at 30 cm upward from the channel bottom. Ground water samples will be taken from piezometers at the depth which will be defined in addition to present state found at the piezometers prior the sample is taken.

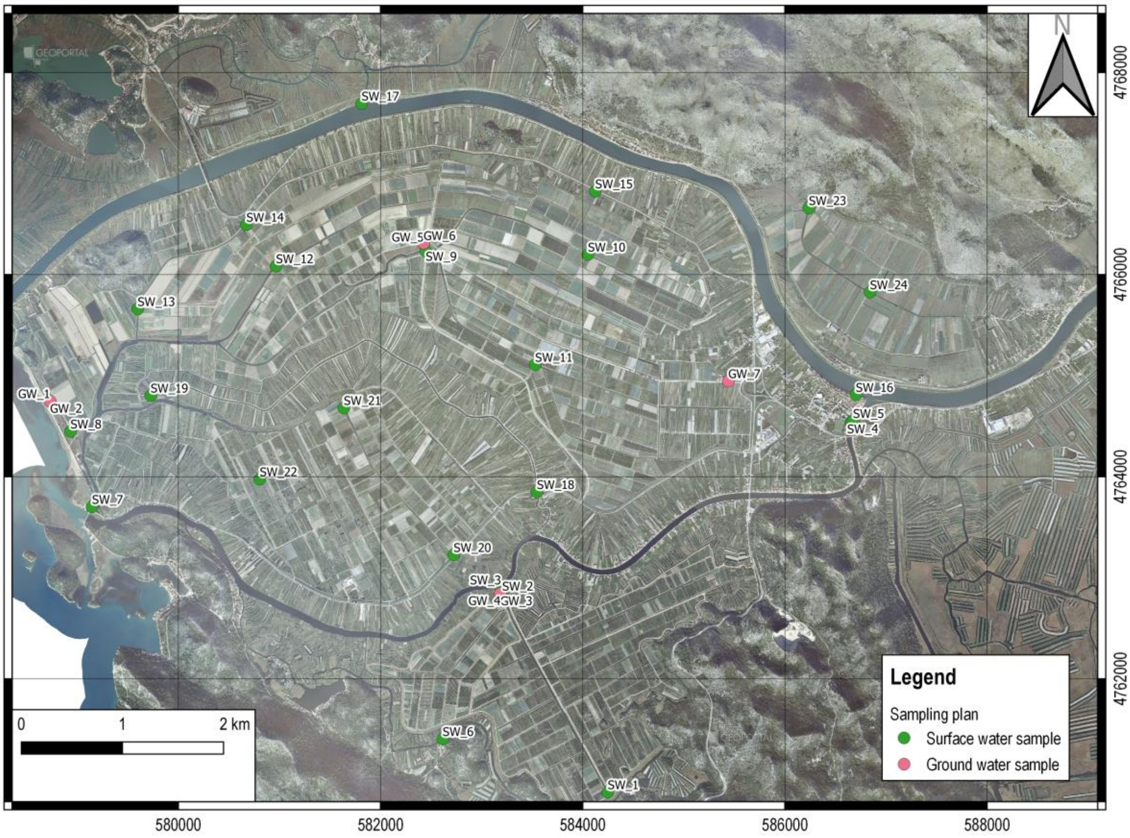

Figure 28 Locations for in-situ water samples to be taken

Specifications of coordinates of monitoring locations have been identified and shown inTable 2. while locations of ground and surface water sampling points have been shown separately in Figure 29 and Figure 30.

Table 2 Coordinates of the water sampling locations within the study area

Sample ID	E (HTRS96)	N (HTRS96)
SW_1	584247.54	4760878.80
SW_2	583204.08	4762862.23
SW_3	583190.57	4762905.25
SW_4	586654.09	4764542.97
SW_5	586673.94	4764552.64
SW_6	582614.39	4761405.10
SW_7	579146.50	4763702.34
SW_8	578932.86	4764448.00
SW_9	582447.09	4766232.52
SW_10	584051.36	4766198.65
SW_11	583529.52	4765108.22
SW_12	580965.86	4766083.72
SW_13	579596.95	4765659.56
SW_14	580673.15	4766494.48
SW_15	584123.94	4766824.63
SW_16	586701.34	4764810.66
SW_17	581812.59	4767693.12
SW_18	583546.75	4763849.08
SW_19	579725.98	4764803.49
SW_20	582723.05	4763226.34
SW_21	581636.78	4764681.08
SW_22	580805.19	4763975.95
SW_23	586236.35	4766659.11
SW_24	586841.52	4765825.75
GW_2	578731.46	4764745.82
GW_1	578730.63	4764748.10
GW_3	583185.45	4762841.51
GW_4	583184.67	4762843.02
GW_5	582425.97	4766315.43
GW_6	582426.03	4766312.78
GW_7	585440.35	4764946.47

Figure 29 Locations for in-situ surface water samples to be taken

Samples of surface and ground water should be taken four times during hydrological year, two times during wet (rain) and two times during dry period (season). Water sampling needs to be done with a specially designed sampler (Figure 8) with a minimum sampling capacity of 500 ml. After sampling is done, water samples will be packed in PE bottles and transported to the laboratory for further analyses.

Figure 30 Location for in-situ ground water samples to be taken

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