environments

Supplementary Materials

Hydrogeological and Hydrochemical Regime Evaluation in Flamouria Basin in Edessa (Northern Greece)

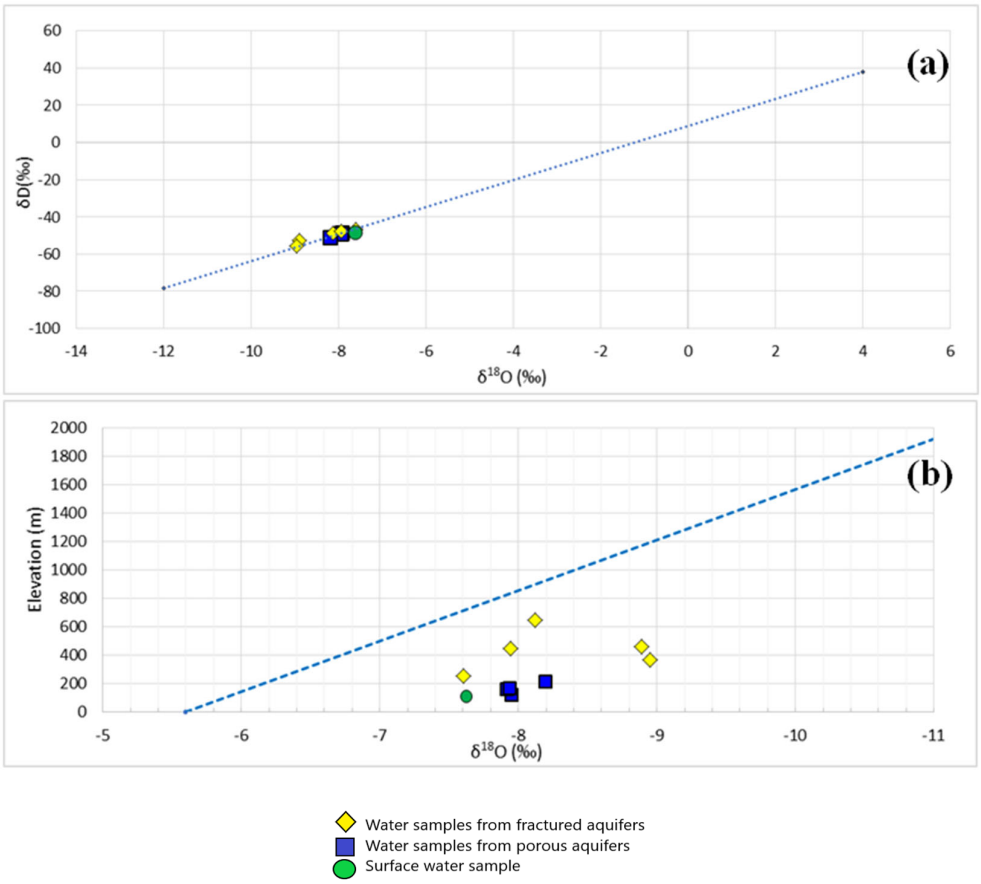

Figure S1. (**a**) Projection of the isotope concentrations in relation with the Hellas MWL for the July 2017 period. (**b**) Correlation between δ18O (‰) and the recharge altitude for the July 2017 period (change line between the isotope composition and the altitude according to the GNIP network).

Table S1. Groundwater level measurements campaign.

Borehole	Aquifer type	Altitude (m)	Groundwater Level (GL) Measurements (m)			
			May 2017	September 2017	May 2018	ΔGL (m)
WLM1	Porous	164	0.00	2.20	0.00	2.20
WLM4	Porous	188	8.25	12.50	7.70	9.50
WLM4	Porous	211	28.31	34.30	-	31.00
WLM6	Porous	197	13.36	15.13	-	14,24
WLM7	Porous	177	10.51	14.20	10.20	11.63
WLM7	Porous	187	15.25	10.30	14.86	13.47
WLM9	Porous	170	5.46	8.36	4.93	6.25
WLM14	Porous	221	38.63	44.35	36.7	40.00
WLM15	Porous	211	26.61	30.20	-	28.40
WLM16	Porous	196	24.35	29.90	-	27.12
WLM18	Porous	120	-	8.820	8.90	8.86
WLM20	Karstic	184	91.36	94.10	85.20	90.22
WLM22	Porous	192	49.28	49.62	47.80	48.9
WLM28	Fractured	347	22.43	40.77	31.10	31.43
WLM30	Porous	245	27.13	31.00	-	29.06
WLM32	Porous	238	5.93	-	-	5.93
WLM35	Fractured	500	11.26	17.01	6.65	11.64
WLM36	Fractured	591	18.23	17.8	14.00	16.67

Table S2. List of infiltration coefficients from Civita and De Maio [30] and Kazakis and Voudouris [26].

Hydrogeological Complexes	Infiltration Coefficient
Coarse alluvial deposits	0.7–0.9
Limestone	0.8–1.0
Dolostone	0.6–0.7
Sand deposits	0.8–0.9
Clay, silt, peat	0.1–0.2
Fissured volcanites	0.8–0.9
Flysch deposits	0.2–0.3
Pyroclastic rocks	0.4–0.6
Metamorphic rocks	0.1–0.2

Table S3. Parameters classes for the PNA methodology from Busico et al. [36].

Unsatured Zone Protection[a]		Topography[b] (% slope)		Depth to Water[a] (m)	
Rating	**Type**	**Rating**	**Range**	**Rating**	**Range**
10	Karst limestone	10	< 5	10	-
9	Limestone calcarenites	9	5–10	9	0–5
8	Recent lavas	8	10–15	8	5–10
7	Alluvial and fluvio sands	7	15–19	7	-
-		6	19–24	6	10–20
5	Siltstone, tuff, igneous	5	24–29	5	-
4	Metamorphic and old volcanic formation	4	29–34	4	20–50
3	Alluvial silt, shales	3	34–39	3	-
-		2	39–44	2	> 50
1	residual soil	1	> 44	1	-
Land Use[d] (Amount of Fertilizer for Kind of Crops)		**Recharge + Irrigation[c] (mm/year)**		**Wells Density[d] (N^w/Km^2)**	
Rating	**Range**	**Rating**	**Type**	**Rating**	**Range**
1	Pasture, forest, bare land	1	0–25	1	0
2	Olive grooves	2	25–50	2	1–2
3	Vegetable	3	50–70	3	3–4
4	Orchads and citrus	4	70–100	4	5–6
5	-	5	100–120	5	6–7
6	Urban areas	6	120–150	6	8–9
7	-	7	150–180	7	10–11
8	-	8	180–220	8	12–13
9	-	9	220–300	9	14–15
10	Cereals	10	-	10	16–17
Soil Nitrogen Content[e] (%)					
Rating	**Range**				
1.04	> 0.5				
1.02	0.22–0.5				
1.00	0.15–0.22				
0.98	0.1–0.15				
0.96	< 0,1				

Table S4. Isotopic ratio statistic for the sampled groundwaters.

Ion Ratios	Mean Value	Max Value	Min Value	St. Dev.
Na/K	13.33	74.43	2.32	20.51
Mg/Ca	0.61	0.92	0.13	0.24
Na/Cl	2.50	4.47	0.85	1.12
(Ca+Mg)/(Na+K)	27.14	41.83	15.12	9.29
$(Ca+Mg)/HCO_3$	1.09	1.38	0.99	0.11
SO_4/Cl	5.36	9.59	1.16	2.72
Cl/HCO_3	0.02	0.04	0.01	0.01
Mg/(Mg+Ca)	0.36	0.48	0.12	0.11
Cl/SO_4	0.28	0.86	0.10	0.22
$Cl/(CO_3+HCO_3)$	0.02	0.04	0.01	0.01

Supplementary Information 1: ET Formula

$$\boldsymbol{I} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{12}} \left(\frac{\boldsymbol{T}}{\boldsymbol{5}}\right)^{\boldsymbol{1.514}}$$

$$a = 0.49239 + 1792 \times 10^{-5} \times I - 771 \times I^2 + 675 \times 10^{-9} \times I^3$$

Supplementary Information 2: Regression line in Figure S1b

The regression equation in Figure S1b can be obtained by a regression analysis of the annual average values of $\delta^{18}O$ in groundwater and elevations: $\delta^{18}O = -356.12\ h - 1994.3$ ($R^2 = 1$, n = 10), where h is the elevation, and the unit is m. It was found that the elevation gradients of the stable isotope values ($\delta^{18}O$) of groundwater in the study area were –0.36%/100 m. This value is in the range of –0.15 ‰ to –0.50 ‰ [1] and –0.10 ‰ to –0.60 ‰ [2] applied to most regions around the world. According to Figure S1b, most points are projected below the line which indicate how the recharge altitude is higher than that at which the sampling took place. The annual stable isotope values ($\delta^{18}O$) of groundwater for the period of July 2017 have significant correlations with the elevation (n = 10, $R^2 > 0.63$).

1. Clark, I.D.; Fritz, P. *Environmental Isotopes in Hydrogeology*; CRC Press/Lewis Publishers: Florida, USA, 1997.
2. Mook, W.G. Isotope fractionation processes. In *Introduction to Isotope Hydrology;* CRC Press Taylor & Francis Group: Florida, USA, 2005.