Supplementary Information

Model-based analysis of the link between groundwater table rising and the formation of solute plumes in a shallow stratified aquifer

Simone Varisco[1], Giovanni Pietro Beretta[1], Luca Raffaelli[2], Paola Raimondi[3], Daniele Pedretti[1,*]

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, 20133, Milan, Italy (simone.varisco17@gmail.com, giovanni.beretta@unimi.it, daniele.pedretti@unimi.it

[2] Consultant, via F. Baracca 2, Barlassina (MB), Italy (info@studioraffaelli.it)

[3] Consultant, via Don Gnocchi 8, Lierna (LC), Italy (paolinaraimondi@gmail.com)

* corresponding author

Contents

1 Additional information on the geological background

Three main geological units characterize the area: the subsyntema of Agro Nocerino Sarnese (VEF2b), the Casalnuovo Casoria Unit (“Unità di Casalnuovo Casoria”, UCC), and the Campanian Ignimbrite (“Ignimbrite Campana”, IC).

The VEF2b lies between the current ground surface and the erosion and/or non-deposition surface that affects the top of the IC. It includes the distal and intermediate pyroclastic deposits of the Mt. Vesuvius and the Phlegraean Fields and the alluvial sediments deposited by a local river (river Sebeto). The VEF2b deposits have highly variable textures, which include centimetric-scale alternations of volcano-clastic silt mixed with sandy-silt of flood plains and muddy levels associated with marshy environment. Peat layers were also occasionally identified. The average thickness of the VEF2b ranges between 1-2m in the study area.

The UCC includes pyroclastic deposits covering a time interval between the deposition of the IC and the eruption of Avellino (between 39 and 3.8 thousand years ago). It is characterized by a white and gray highly laminated tuff in the lower part, with interlayers of white pumice levels. In the upper part of the UCC, a level of pumice immersed in a yellowish matrix of ash-fall deposits is sometimes found. The UCC base often rests on a brown paleosol that develops on the topsoil of the IC and/or on alluvial and/or colluvial deposits. The UCC has a variable thickness between a few cm up to 2 m in the study area.

The IC consists of pyroclasts, mostly ignimbrite deposits, deposited some 39 thousand years ago. It formed as a consequence of the major eruption that took place in the former caldera of the Phlegraean Fields, located 20 km west of Mt. Vesuvius in the western outskirts of the city of Naples and the Gulf of Pozzuoli. The IC is present on the subsurface of the entire PON, although it does not outcrop. The IC is associated with a low-permeability tuff horizon, with strong lateral and vertical spatial discontinuity. In the study area, the IC thickness is about one meter, although in other parts of the Campanian plain it can vary from a few meters to 40 m.

2 Stratigraphic cross-sections of the contaminated site

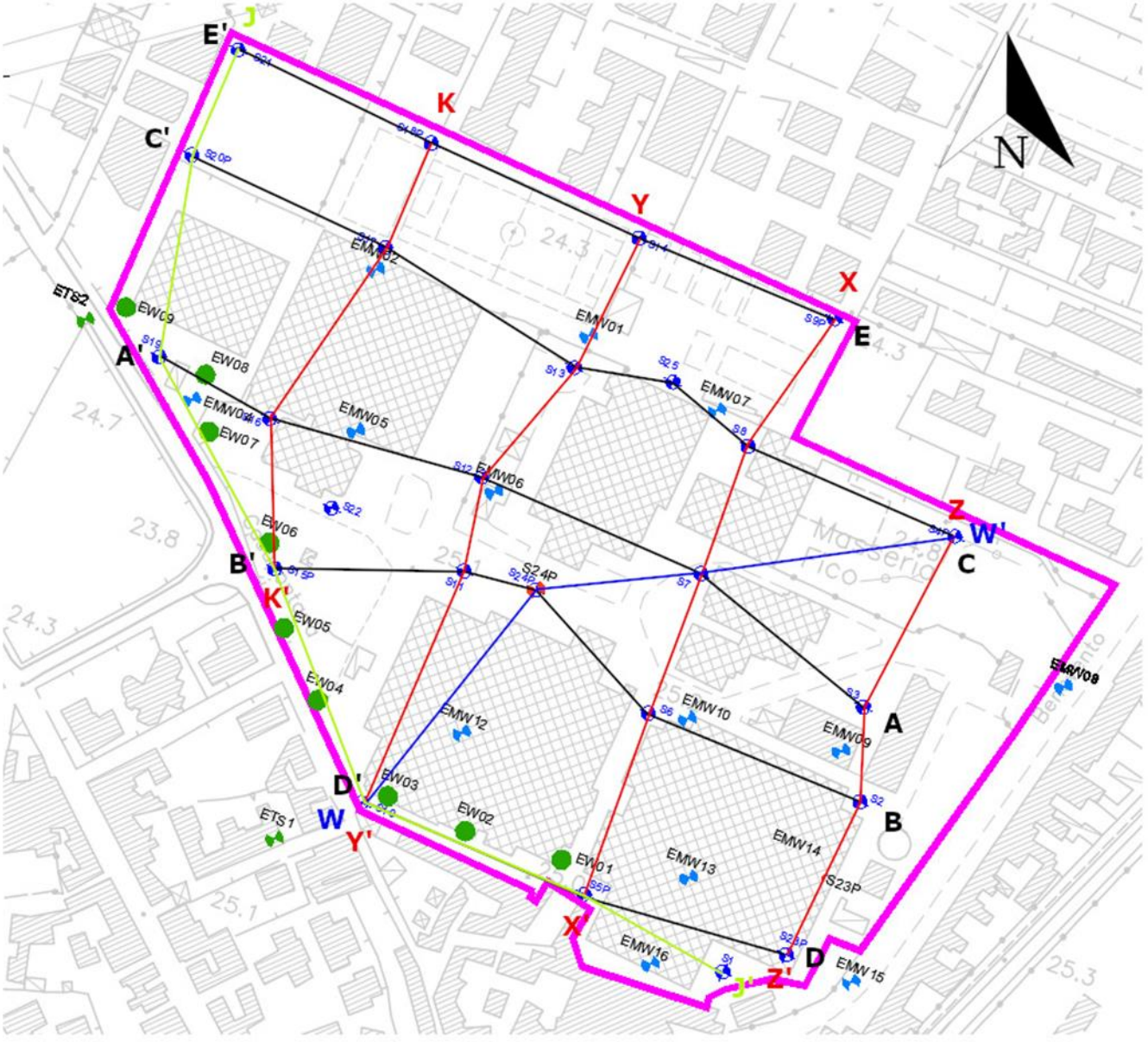
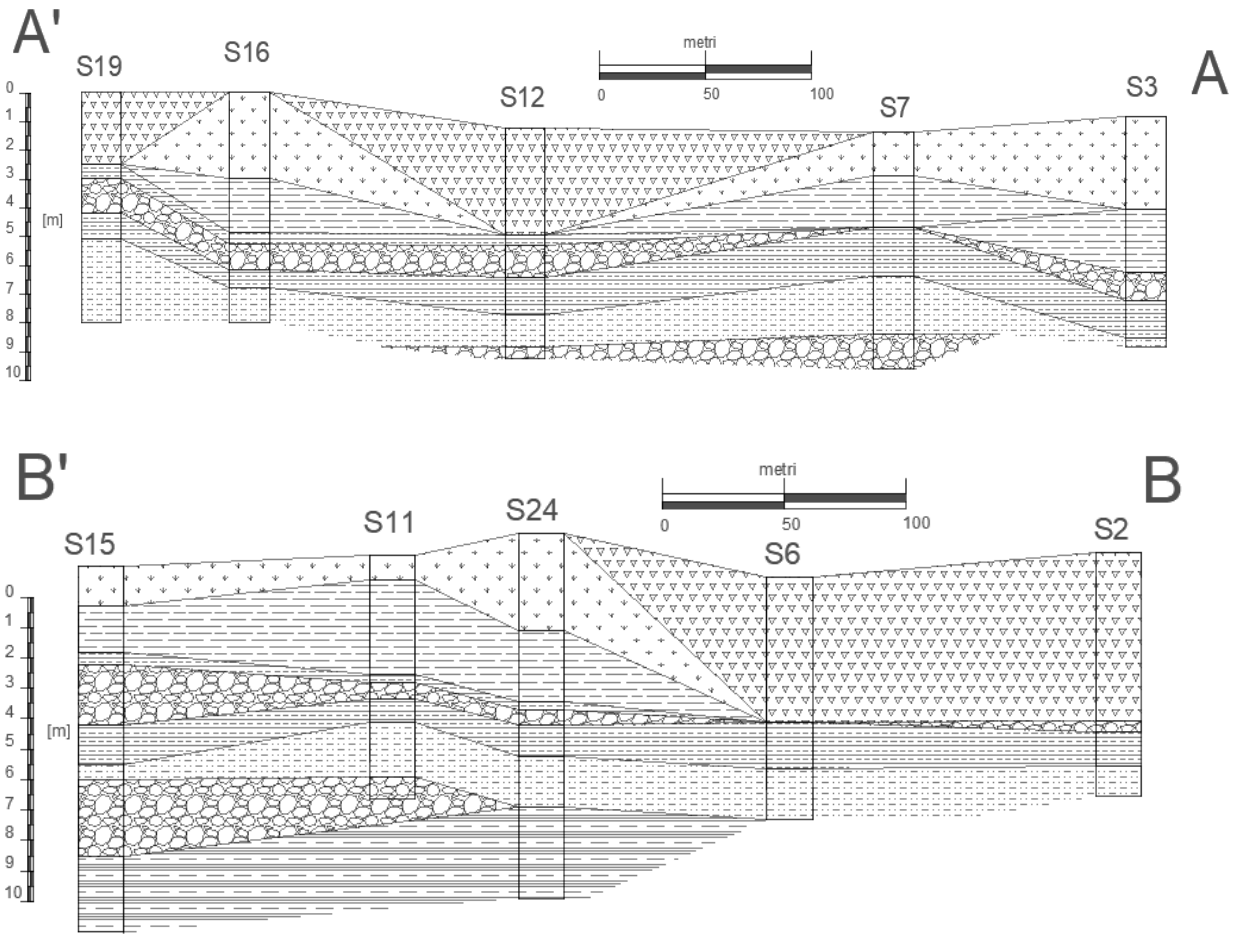
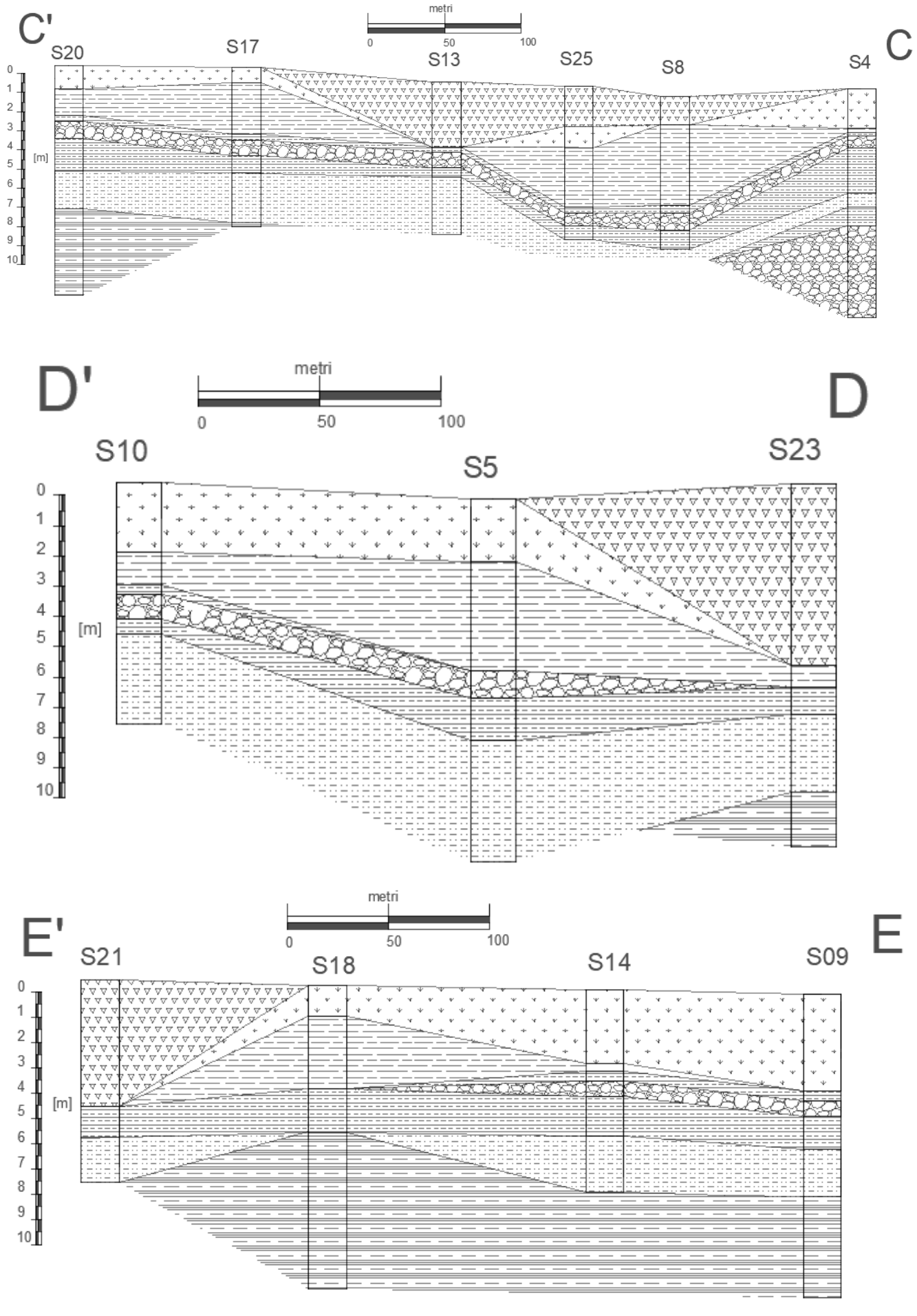


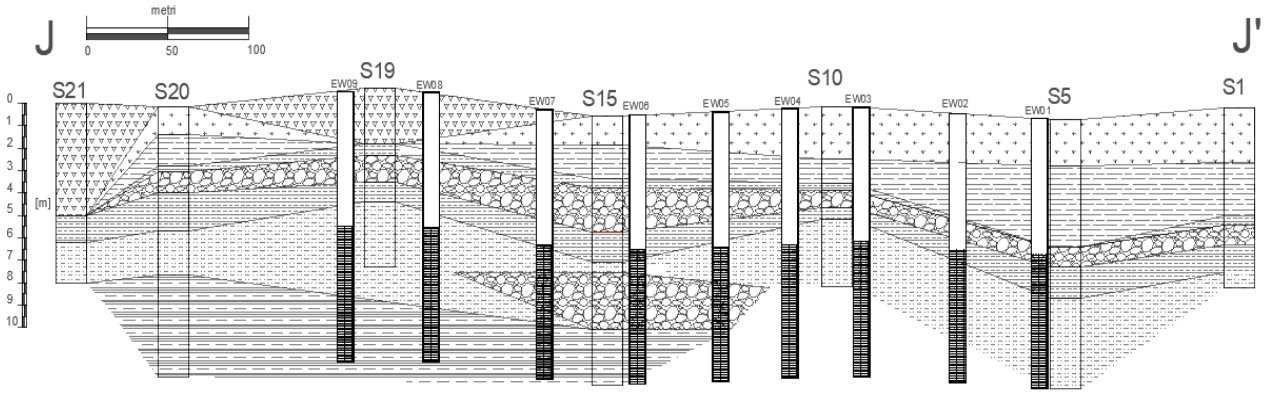
Figure S1 Traces of the eleven stratigraphic cross-sections. The purple line represents the external boundary of the former industrial setting.

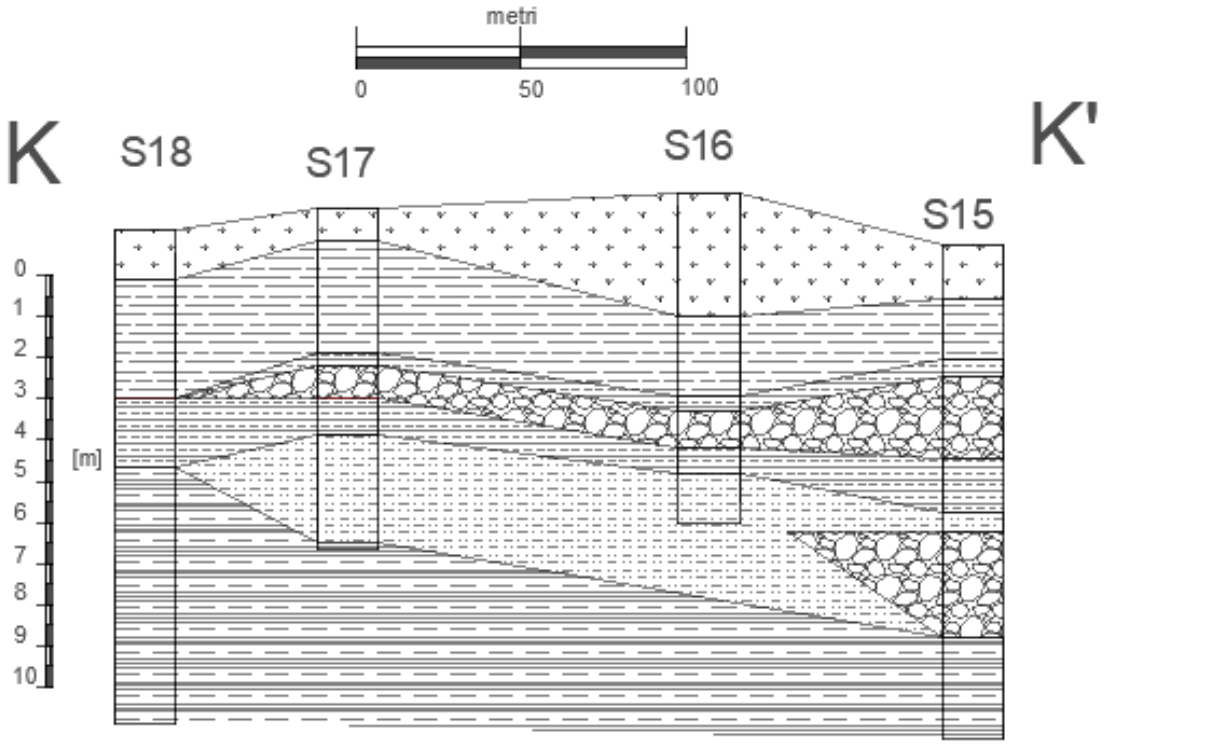
Table S1 Legend of cross-section lithologies

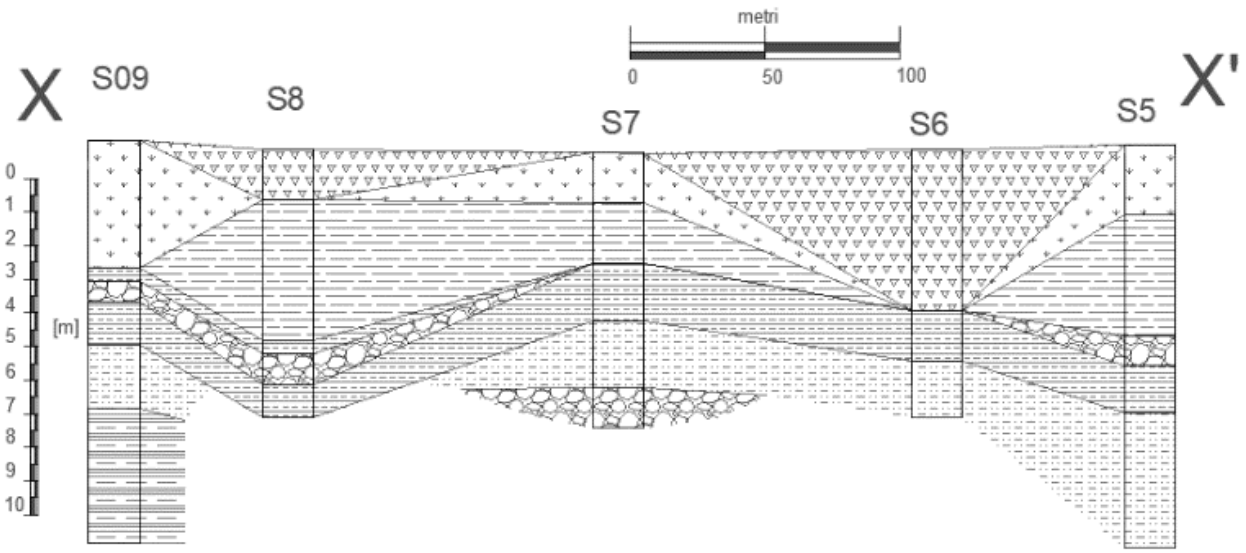
	Backfilling material
	Re-arranged natural topsoil
	Fluvial and lake deposits. ash deposits re-arranged by fluvial transport
	Paleosols
	Weathered pumice
	Re-arranged volcanic ash
	Sandy silt

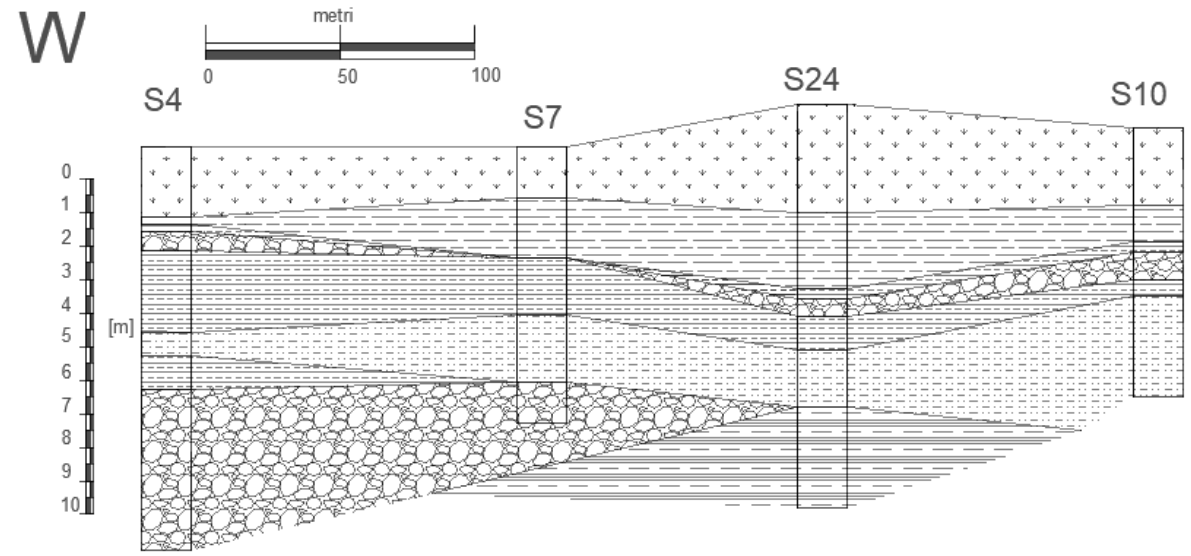


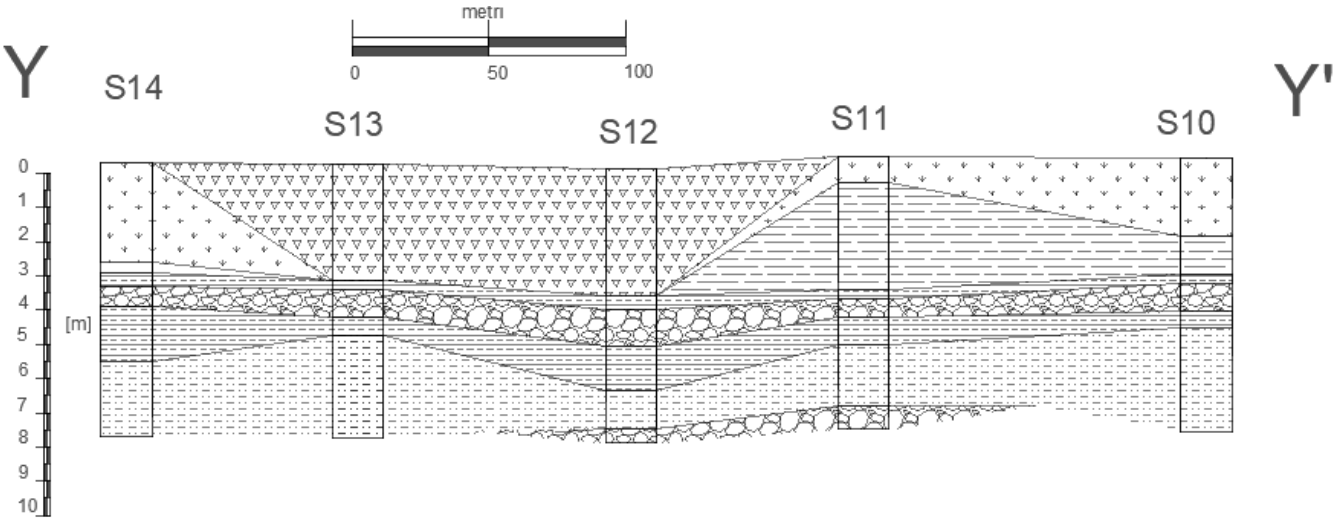

C'
C
metri
0
50
100
S20
S17
S13
S25
S8
S4
[m]
0
1
2
3
4
5
6
7
8
9
10
D'
D
metri
0
50
100
S10
S5
S23
[m]
0
1
2
3
4
5
6
7
8
9
10
E'
E
metri
0
50
100
S21
S18
S14
S09
[m]
0
1
2
3
4
5
6
7
8
9
10

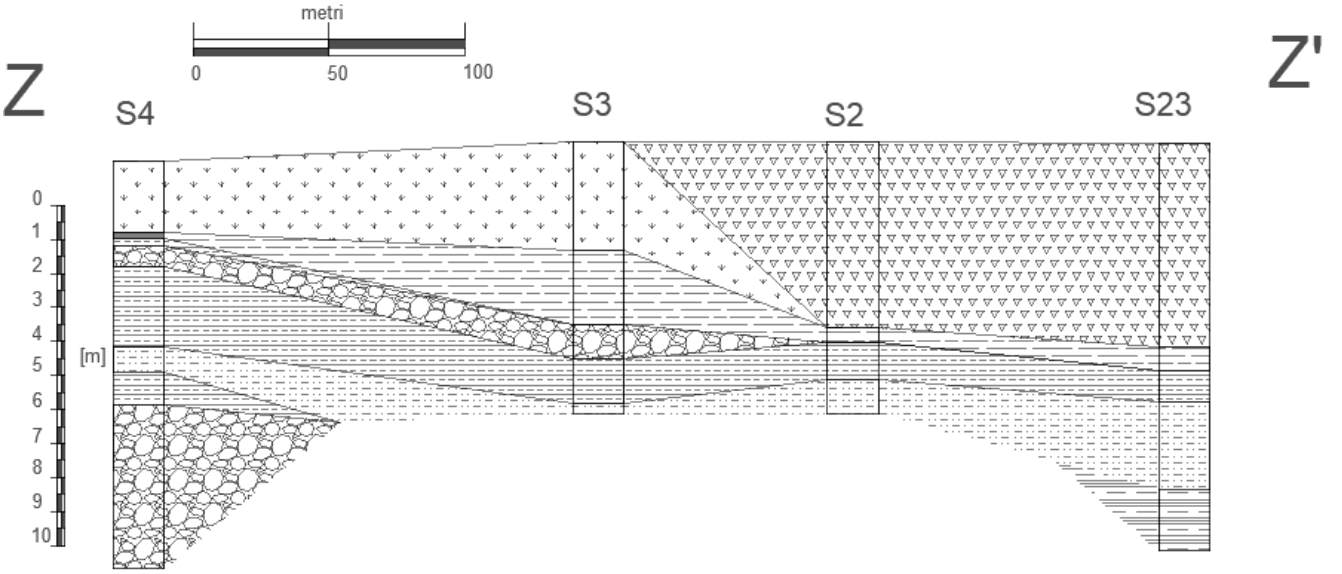

J
J'
metri
0
50
100
S21
S20
S19
S15
S10
S5
S1
EW09
EW08
EW07
EW06
EW05
EW04
EW03
EW02
EW01
[m]


metri
0
50
100
K
K'
S18
S17
S16
S15
[m]


metri
0
50
100
X
X'
S09
S8
S7
S6
S5
[m]


W
W'
metri
0
50
100
S4
S7
S24
S10
0
1
2
3
4
5
6
7
8
9
10
[m]


Y
Y'
metri
0
50
100
S14
S13
S12
S11
S10
0
1
2
3
4
5
6
7
8
9
10
[m]

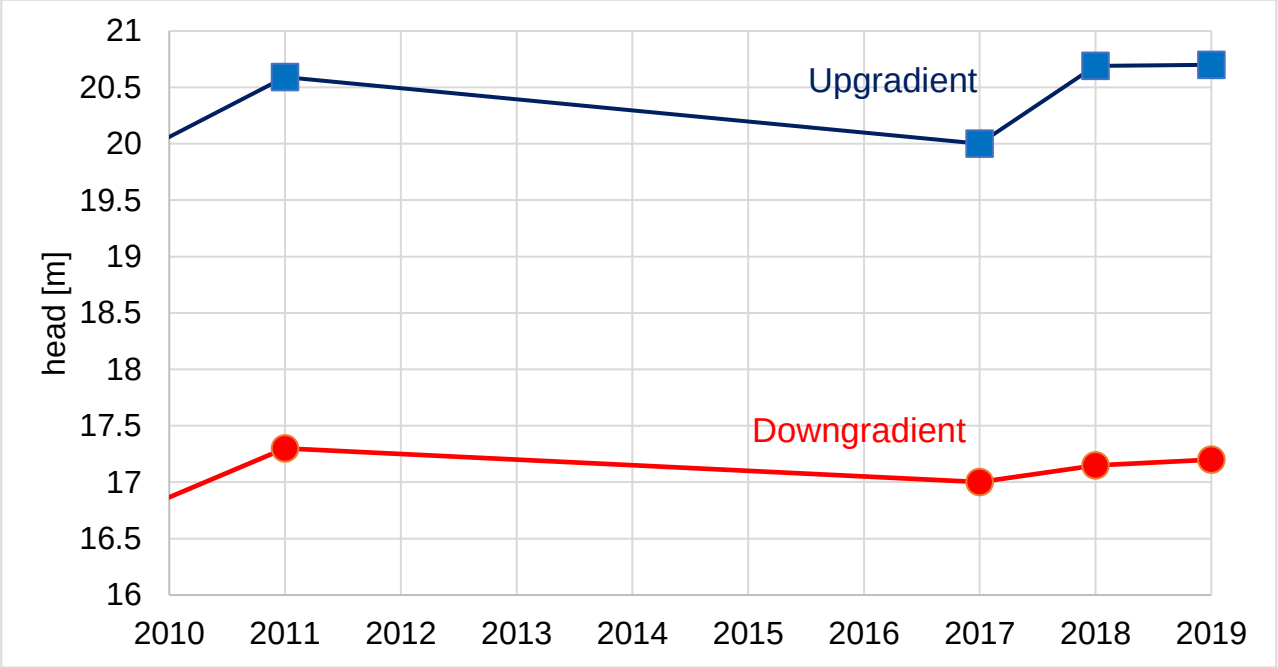

Z
Z'
metri
0
50
100
S4
S3
S2
S23
0
1
2
3
4
5
6
7
8
9
10
[m]

3 Interpolated surfaces of the model layers

Table S2 Levels of separation (m) between the layers for each borehole and used to create the interpolated surfaces with ModelMuse 4.3

	Number of layer									
Borehole	Top	1	2	3	4	5-8	9	10	11	12
S01	25.47	24.07	21.67	21.27	18.87	17.67	15.67	13.67	11.67	10.00
S02	24.77	21.07	20.57	20.07	18.17	17.07	15.07	13.07	11.07	10.00
S03	25.00	22.00	21.5	21.00	18.6	17.3	15.30	13.30	11.30	10.00
S04	25.52	23.42	23.22	23.02	20.92	18.52	16.52	14.52	12.52	10.00
S05	25.47	23.87	20.57	20.27	17.87	16.47	14.47	12.47	10.47	10.00
S06	25.3	21.58	21.08	20.58	18.58	17.53	15.53	13.53	11.53	10.00
S07	25.00	23.5	22.7	22.2	20.2	18.2	16.20	14.20	12.20	10.00
S08	25.81	24.61	20.41	20.01	17.61	16.61	14.61	12.61	10.61	10.00
S09	25.61	22.51	22.41	22.01	19.91	18.61	16.61	14.61	12.61	10.00
S10	26.18	23.88	22.28	21.78	19.88	19.08	17.08	15.08	13.08	10.00
S11	26.71	25.91	22.81	22.41	20.41	18.61	16.61	14.61	12.61	10.00
S12	25.7	22.1	21.6	21.1	19.00	17.7	15.70	13.70	11.70	10.00
S13	25.77	22.87	22.37	22.07	19.77	19.27	17.27	15.27	13.27	10.00
S14	25.6	22.7	22.4	22.00	19.9	18.3	16.30	14.30	12.30	10.00
S15	25.7	24.4	22.9	22.5	19.00	17.7	15.70	13.70	11.70	10.00
S16	26.87	24.17	22.27	21.87	19.47	18.87	16.87	14.87	12.87	10.00
S17	26.32	23.52	23.02	22.52	20.22	19.32	17.32	15.32	13.32	10.00
S18	26.00	24.81	22.9	22.4	20.4	18.71	16.71	14.71	12.71	10.00
S19	26.86	25.16	24.66	24.06	21.36	20.46	18.46	16.46	14.46	10.00
S20	26.3	25.1	23.7	23.4	21.00	19.3	17.30	15.30	13.30	10.00
S21	26.18	22.38	21.88	21.38	19.38	18.18	16.18	14.18	12.18	10.00
S22	26.00	22.2	21.7	21.2	19.2	18.00	16.00	14.00	12.00	10.00
S23	25.89	23.69	21.89	21.49	19.29	18.29	16.29	14.29	12.29	10.00
S24	26.71	21.81	21.31	20.81	18.81	17.91	15.91	13.91	11.91	10.00
S25	25.79	22.79	20.49	20.19	18.19	17.19	15.19	13.19	11.19	10.00

4 Time-dependent constant-head boundary conditions



5 Pumping rates used in the numerical model

Table S3 Pumping rates, as m^3/h,

year	EW01	EW02	EW03	EW04	EW05	EW06	EW07	EW08	EW09
2003	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0
2006	0.8	2.8	0.8	0.8	3.5	3.5	0.8	0.6	0.17
2007	0.8	2.8	0.8	0.8	3.5	3.5	0.8	0.6	0.17
2008	0.8	2.8	0.8	0.8	3.5	3.5	0.8	0.6	0.17
2009	0.8	2.8	0.8	0.8	3.5	3.5	0.8	0.6	0.17
2010	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0.17
2011	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0.17
2012	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0.17
2013	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0.17
2014	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0.125
2015	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0
2016	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0
2017	1.08	2.02	0.58	2.09	1.3	2.23	1.12	0.97	0
2018	0.97	4.6	1.12	1.98	0.86	2.23	1.22	1.04	0
2019	0.97	4.6	1.12	1.98	0.86	2.23	1.22	1.04	0

6 Calibration plots and sensitivity analysis

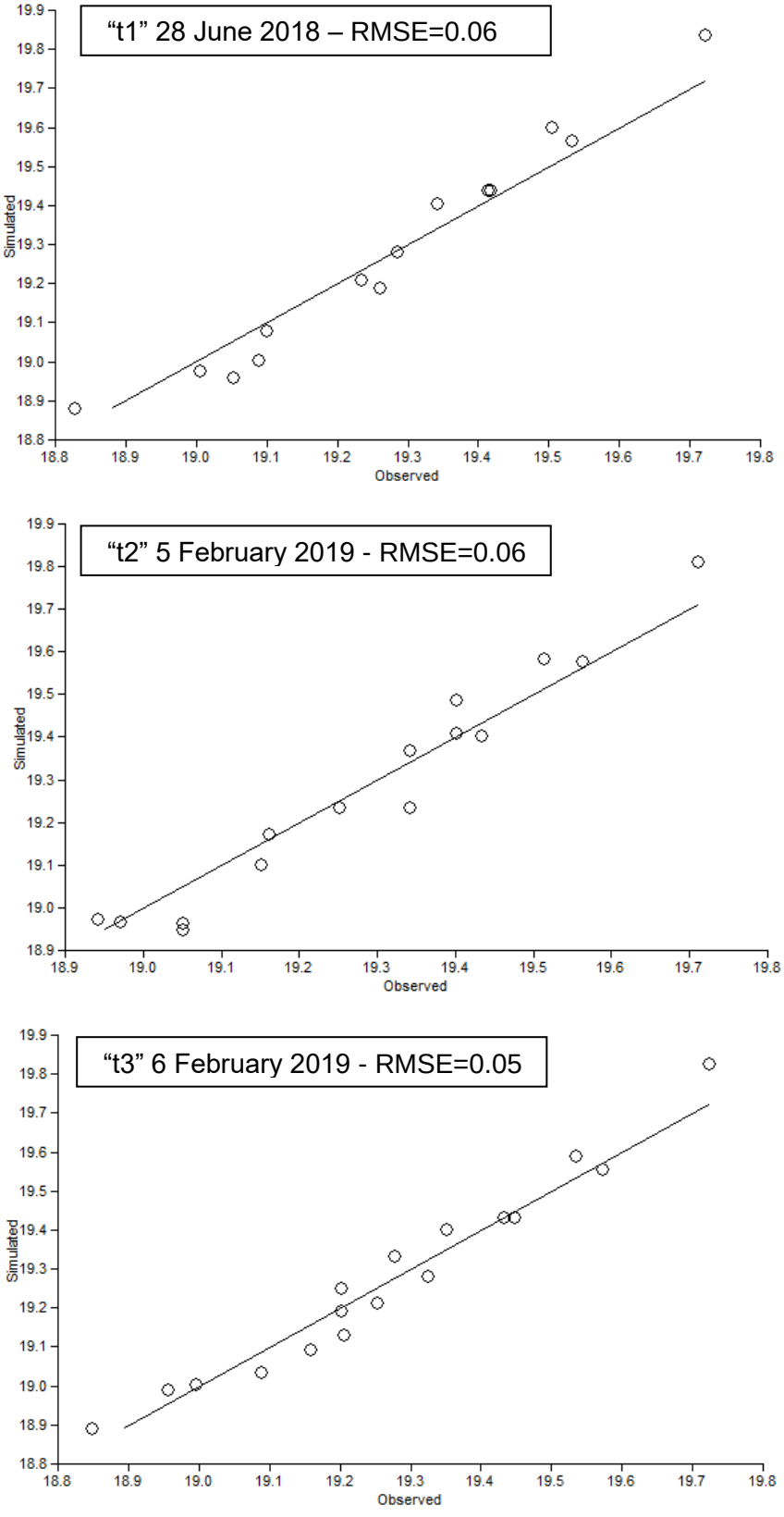


Figure S2 – Calibration of the model for the different datasets.

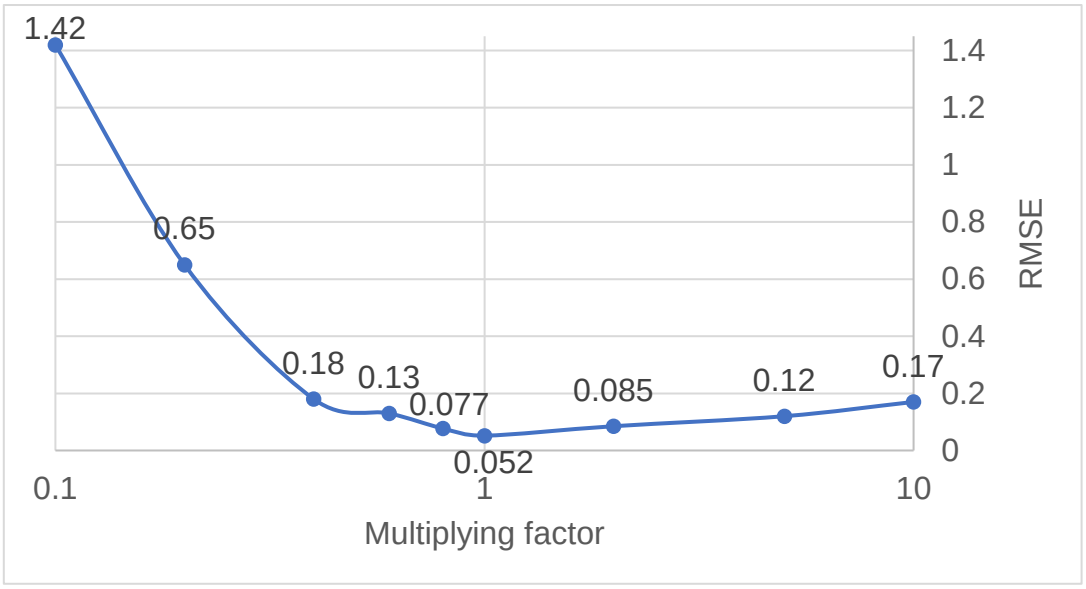


Figure S3 – Sensitivity analysis on parameter “hydraulic conductivity, *K*”, performed on dataset “t3”.