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Land subsidence due to the overexploitation of the aquifer at the Valtonera village

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This research focus on land subsidence due to the overexploitation of the aquifer in the village of Valtonera. The area of interest is located in the Amyntaio basin at Florina prefecture. The systematic overexploitation of the aquifer by both the open pit coal mine and the wells for irrigation purposes have led to a significant drawdown of the ground water level, during the last decades (Tzampoglou and Loupasakis, 2016). The hydrogeological and tectonic setting of the site in conjunction with the geotechnical parameters of the formations, trigger extensive land subsidence and surfaces ruptures. In detail, two parallel ruptures with NE-SW direction have been noticed which are causing significant damage to infrastructure farmlands and road network. The main objects of this research are the simulation of the failure mechanism and the calculation of the differential vertical displacements using the Plaxis three-dimensional finite element code.

Regarding the geotechnical and tectonic setting, the Valtonera village is intersected by a probable fault which extends with NNE - SSW direction. It is worth to mention that due to the fault offset, the thickness of the Perdikas formation at the SE'ern side is increased. The geological stratigraphic (Figure 2A) is composed of (from the new ones to the older ones):

Alluvial deposits: They consist of silty-clay with sand. Besides the fact that they present high compression index, their occurrence near to the surface lead to the conclusion that the ground water level drop does not influence them.

Perdikas formation: It consist of alternating layers of silty-clayey sand, sandy silty-clay, sandy gravels and organic silty-clay. Its present high compression index, especially for the sandy silty-clays and the organic silty-clays horizons. So, it is susceptible for the activation of land subsidence.

Proastio formation: It consist of alternating horizons of silty-clayey sand, sandy silty-clays, sandy gravels and organic silty-clays. Besides its high compression index, their contribution to the land subsidence mechanism is downgrade due to the fact that the participation of clay horizons to this formation is small (Tzampoglou and Loupasakis, 2017)

The soil data parameters can be summarize in Table 1(Tzampoglou and Loupasakis, 2017).

Table 1. Soil data set parameters

	Alluvial Deposits	Perdikas' Formation				Proastio Formation			
		Silty clayey sand Upper Strata (till 40m)	Sandy silty clay Upper Strata (till 40m)	Silty clayey sand Dipper Strata (till 90m)	Sandy silty clay Dipper Strata (till 90m)	Silty clayey sand Upper Strata (till 90m)	Sandy silty clay Upper Strata (till 90m)	Silty clayey sand Dipper Strata (till 160m)	Sandy silty clay Dipper Strata (till 160m)
v	0.30	0.30	0.30	0.3	0.30	0.30	0.30	0.3	0.3
γ_{unsat} (kN/m^3)	22.56	20.04	18.16	20.04	18.16	19.92	19.02	19.92	19.02
γ_{sat} (kN/m^3)	24.05	22.16	21.49	22.16	21.49	22.63	22.45	22.63	22.45
C (kN/m^2)	121.9	78.0	91.4	78.0	93.8	91.4	45.1	0.0	45.1
φ (^{0})	28.8	20.0	27.4	20.0	24.3	27.4	25.0	41.0	25.0
Kx (m/day)	0.09	2.94	0.16	2.94	0.16	5.66	0.63	5.66	0.63
Ky (m/day)	0.09	2.94	0.16	2.94	0.16	5.66	0.63	5.66	0.63
Kz (m/day)	0.09	2.94	0.16	2.94	0.16	5.66	0.63	5.66	0.63
Eoed (kN/m^2)	7596	7059	9756	12724	13590	15416	18156	27646	22720
Eref (kN/m^2)	5643	5244	7247	9452	10095	11452	13487	20537	16877

As for the hydrogeological data, evaluating the drawdown contour lines between May 1992 (Dimitrakopoulos, 2001) and May 2016, the maximum level drop reaches the 70 m at the perimeter of the mine and decrease as moving away from it. In the village of Valtornera the level drop varies from 10 to 20 meters. It should be noticed that isolated depression cones can be identified at the southeast of the village due to the overexploitation of for irrigation purposes.

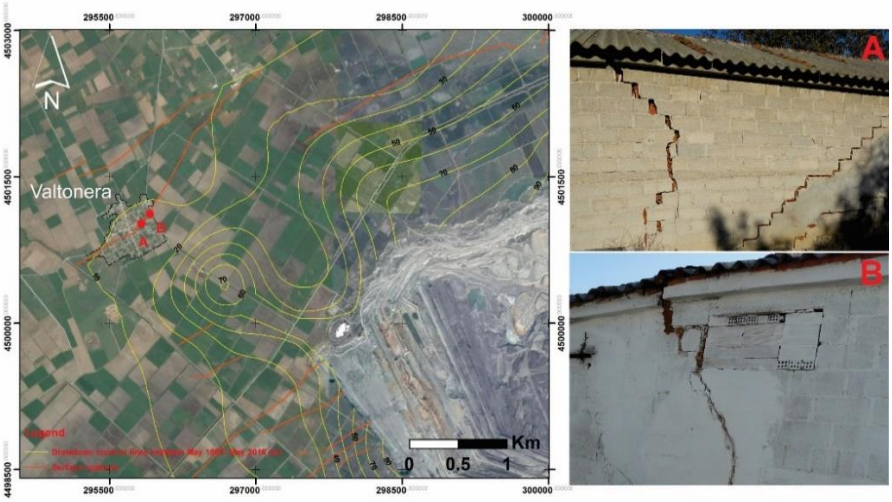
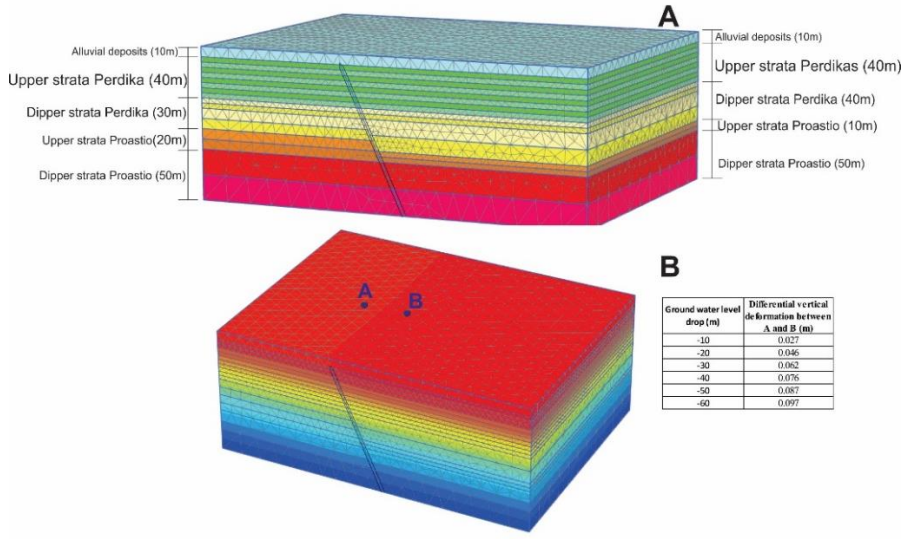


Figure 1. Distribution of the surface ruptures at the Valtonera village in relation with drawdown contour lines.

In order to simulate the land subsidence mechanism by using PLAXIS finite element geotechnical code, highlighting the important role of the ground water level drop, certain assumptions have been made. Firstly, six calculations steps were carried out, in order to gradually drawdown the aquifer from 0 to a level of -60 m. Furthermore, the Perdikas and the Proastio formation were divided into upper and dipper horizons aiming to increase the values of compressibility index in accordance to the stratigraphy depth, while the coarse grain and the fine grain horizons of these formations were set to be equally distributed. Finally, the simulations were conducted by applying the "consolidation analysis" while the constitutive law selected, was the Mohr–Coulomb model.

Taking into account the simulation analysis results, it seems that the vertical displacements increase proportional to the drawdown of the aquifer. The maximum vertical displacements have been noticed at the part where the formation of Perdikas increases. Furthermore, the differential vertical displacement increases in accordance to the level drop, reaching (for level drop around -60m) the value of 0.097 m (Figure 2B). This price is not high due to the fact that the fault doesn't border the aquifer and the Perdikas formation extends at both sides of the fault. It should be noticed that the results of the finite elements analysis are in agreement with the recorded surfaces ruptures offset (Figure 1).



Ground water level drop (m)	Differential vertical deformation between A and B (m)
-10	0.027
-20	0.046
-30	0.062
-40	0.076
-50	0.087
-60	0.097

Figure 2. A. Simplified 3D simulation model of the site at the village of Valtonera, B. The results of deferential vertical displacements due to the level drop of the aquifer.

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References

Dimitrakopoulos, D., 2001. Hydrogeological conditioning of Amyndeon mine. Problems during exploitation and overcoming them. Phd Thesis, National Technical University of Athens, Athens.

Tzampoglou, P., Loupasakis, C., 2016. New data regarding the ground water level changes at the Amyntaio basin-Florina Prefecture, Greece. Bulletin of the Geological Society of Greece. 50, 1006-1015.

Tzampoglou, P., Loupasakis, C., 2017. Evaluating geological and geotechnical data for the study of land subsidence phenomena at the perimeter of the Amyntaio coalmine, Greece. International Journal of Mining Science and Technology. 28, 61-612.