International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:11, No:8, 2017

Study of Landslide Behavior with Topographic Monitoring and Numerical Modeling

ZerarkaHizia, Akchiche Mustapha, Prunier Florent

Abstract**—**Landslide of Ain El Hammam (AEH) has been an old slip since 1969; it was reactivated after an intense rainfall period in 2008 where it presents a complex shape and affects broad areas. The schist of AEH is more or less altered; the alteration is facilitated by the fracturing of the rock in its upper part, the presence of flowing water as well as physical and chemical mechanisms of desegregation in joint of altered schist. The factors following these instabilities are mostly related to the geological formation, the hydro-climatic conditions and the topography of the region. The city of AEH is located on the top of a steep slope at 50 km from the city of TiziOuzou (Algeria). AEH's topographic monitoring of unstable slope allows analyzing the structure and the different deformation mechanism and the gradual change in the geometry, the direction of change of slip. It also allows us to delimit the area affected by the movement. This work aims to study the behavior of AEH landslide with topographic monitoring and to validate the results with numerical modeling of the slip site, when the hydraulic factors are identified as the most important factors for the reactivation of this landslide. With the help of the numerical code PLAXIS 2D and PlaxFlow, the precipitations and the steady state flow are modeled. To identify the mechanism of deformation and to predict the spread of the AEH landslide numerically, we used the equivalent deviatory strain, and these results were visualized by MATLAB software.

Keywords**—**Equivalent deviatory strain, landslide, numerical modeling, topographic monitoring.

I. Introduction

THE AEH landslide movement is an interesting case study to model. As the slide's reactivation appears to have been triggered by local water conditions after a strong rainfall treated by [1], we modeled the problem with a hydro-mechanical finite element formulation.

The several reactivations compel us to look closely at its triggers in order to better understand the mechanisms of its evolution in mass. For that, we used two approaches: topographic surveying, and the equivalent deviatory strain, to predict and to identify the deep of slip surface and to understand the sliding direction and velocity. Furthermore, [2]-[4] demonstrate that topographic surveying allows us to discover and to predict the future evolution of the landslide for taking the safety measures.

II. Study Area

AEH is a mountainous town, situated at 1500 m altitude; the climate of the area is Mediterranean, continental, relatively cold, rainy in winter, hot and dry in summer. Temperatures vary from year to year, from -5 °C to 35 °C with occasional peaks of 40 °C in July and August; the rains are spread over a period of five to six months with heavy rain and snow between November and March. The geology of the study area is characterized essentially by dark gray satin schist's belonging to the metamorphic crystallophyllian base of the massif of the Great Kabylia. Satiny schist has a mean direction of schistosity oriented ENE-WSW with a dip that varies from 40 to 60° to the southeast [5].

The landslide of the city of AEH is important and old landslide in Algeria, which affected urbanized part of the AEH city (Fig. 1). The perpetual reactivation of AEH landslide after each rainfall, we require to research and predict its manifestation and its evolution in future.

Fig. 1 Satellite view of the location of AEH landslide

The alteration product is reddish clay silt which contains fragments of shale and makes up the layer of the embankment. The rate of schist alteration depends on the depth of the layer, exposure to climate hazards, and the circulation of groundwater.

The city of AEH is characterized by the existence of numerous water sources in the catchment leaking. This means that there is a substantial aquifer because the shale formations are a priori permeable in one direction of the cleavage.

From the geotechnical point of view, the presence of water in abundance in this region promotes a physical and chemical alteration of the rock (shale satin which is an indication of old compression clay). Schist of metamorphic origin presents multiple structures which have been exposed to the air. The rock has poor resistance to physical and chemical stresses, and easily deteriorates under the action of frost or rainwater [6].

The presence of water in the soil acts directly on its geotechnical characteristics [7]. It greatly reduces its strength when saturated and affects its stability with the fluctuation of

Hizia Zerarka is with the University of Sciences and Technology Houari Boumediene, Algeria (e-mail: zerarkahizia@yahoo.fr).

the groundwater. This could be a trigger factor of land movements.

III. Topographic Monitoring

The topographic monitoring followed by implantation of the target, is indicated on the map in Fig. 2. The target baseline measurement was conducted in October 2009. The surveys were then carried out on monthly basis. The last measurement was in May 2012 with six-month of interruption. The movements of the targets are plotted along the **Z** axis for each section in the graphs to better monitor and study the movements of the slope.

Measurements are carried out from the AEH area, and allow having indications of the existence of ground movement in the basement. The measurements which are based on measuring the relative position of the point in question by providing a stable reference point, displacement in time of the five cuts made in the field are given by Figs. 3-7.

Based on topographic monitoring, it is notable that the downstream ground movement is relatively more active than upstream. There are also significant peak values over all cuts during the months of April 2011, December2011, April 2012, and May 2012. Finally, it is assumed that heavy rainfall during the months of September 2011(45.3mm / day and 162.5 to 181.6 mm/day source [8]) has caused the notable shifts recorded.

By studying the different graphs, we see that the displacements are largest on-DT DT cuts and ET-ET. The vertical displacements Δz range from -0.5 to 0.5 m can also be seen and point downstream moves differently compared to the upstream side. This explains that the landslide will expand on the upstream side of the slope and also causes movement to the beat of the slope by generating sags and bulges at ground level.

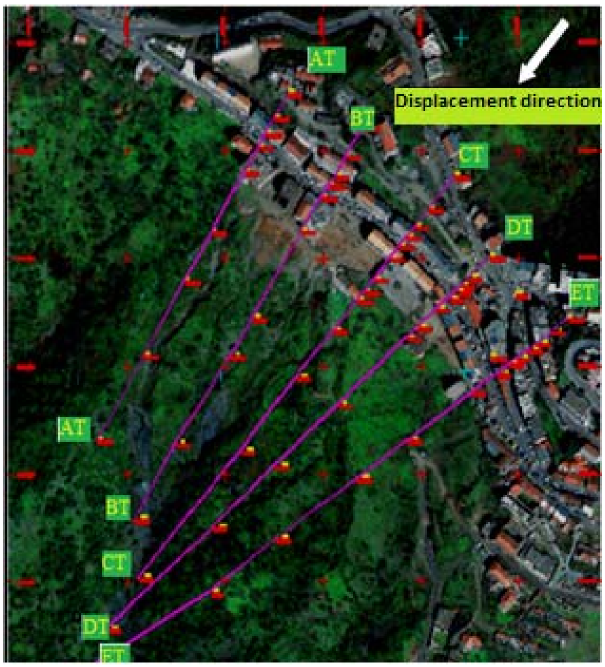

Fig. 2 Satellite photos with the topography monitoring sections

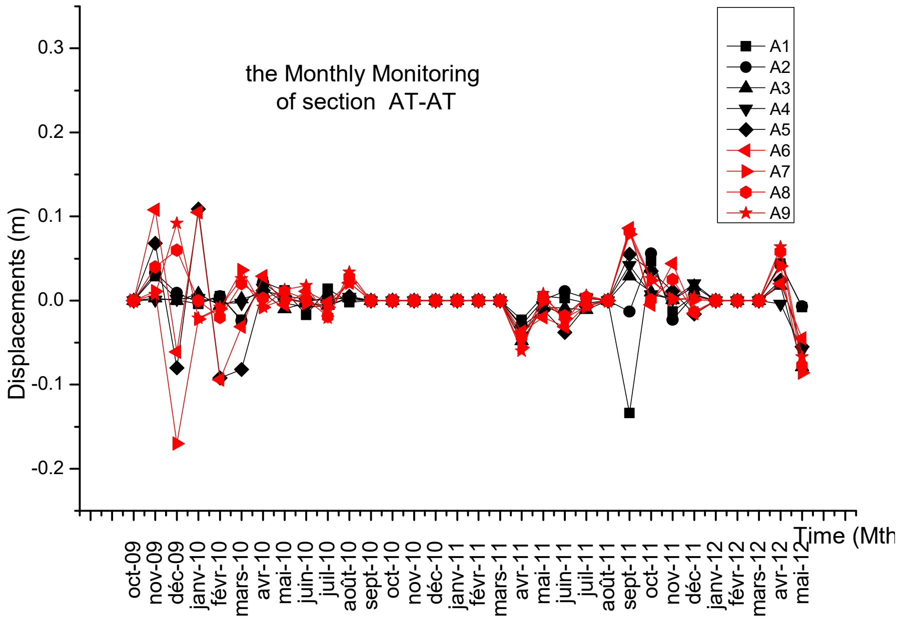

Fig. 3 Displacement of topographic point according to cut AT-AT

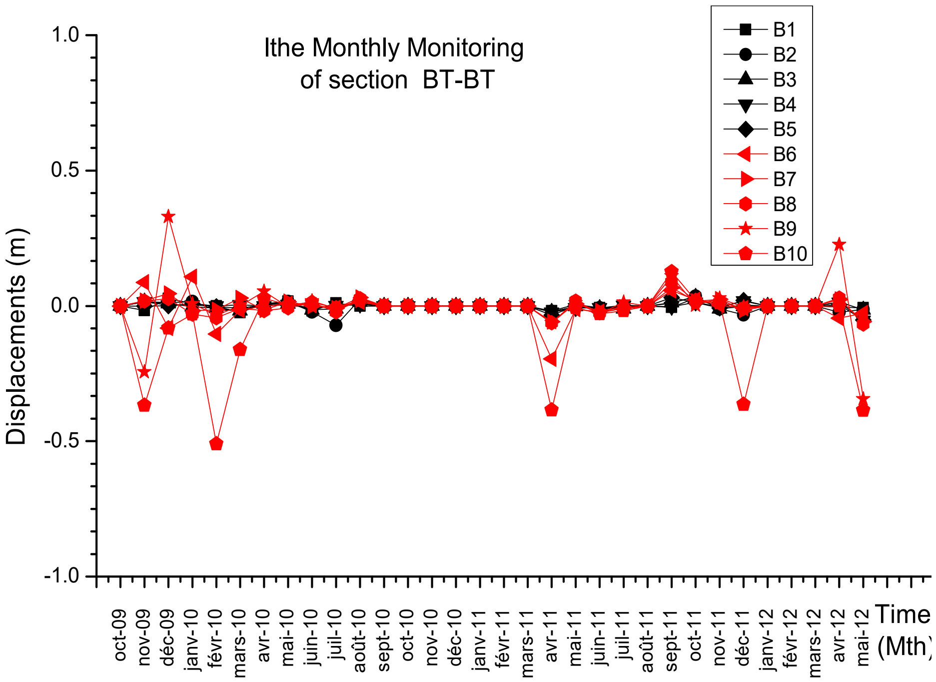

Fig. 4 Displacement of topographic point according to cut BT-BT

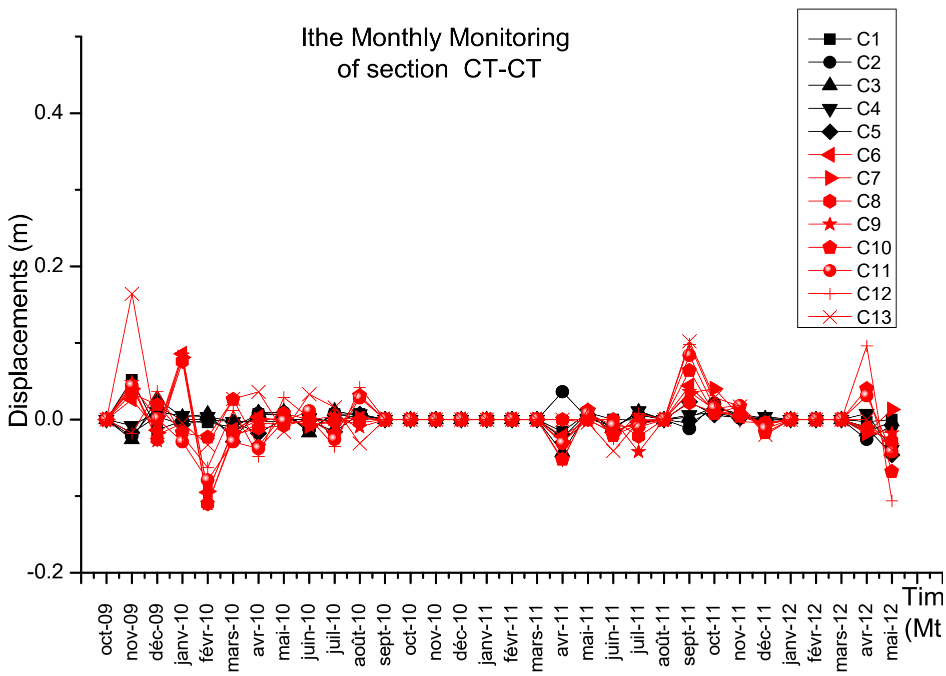

Fig. 5 Displacement of topographic point according to cut CT-CT

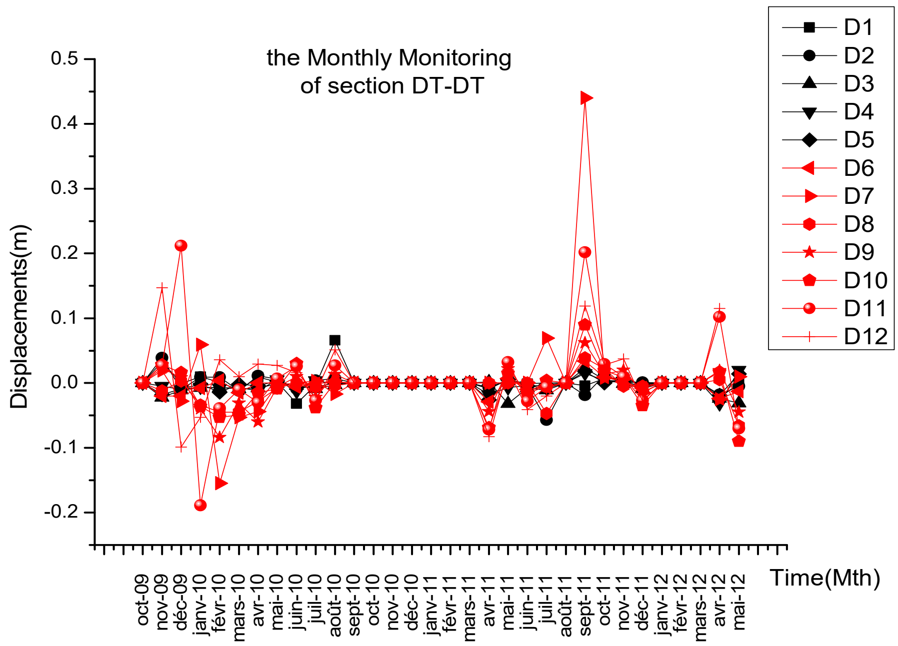

Fig. 6 Displacement of topographic point according to cut DT-DT

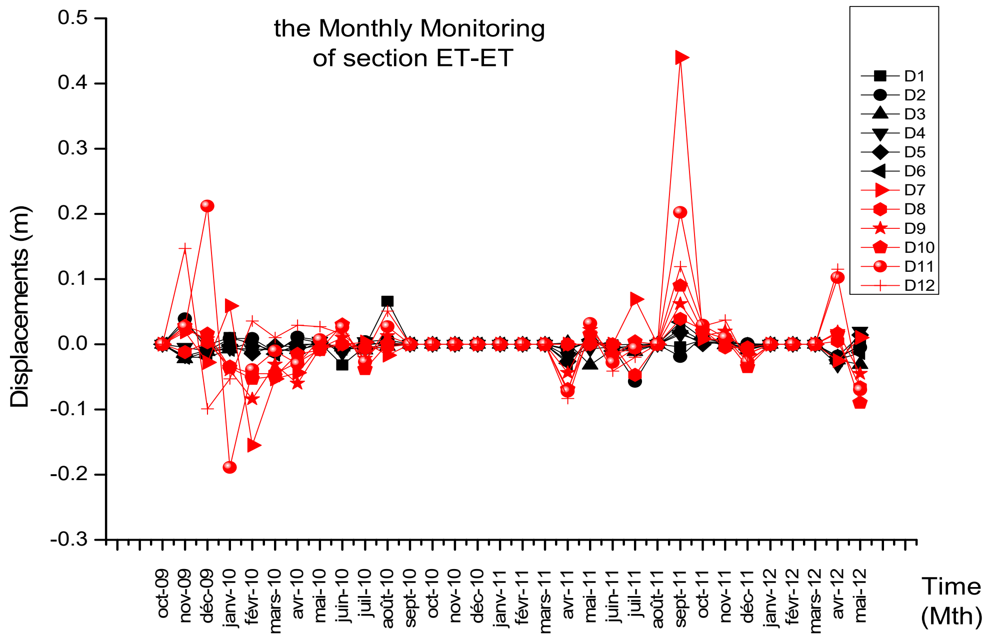

Fig. 7 Displacement of topographic point according to cut ET-ET

IV. Equivalent Plastic Deviatory Strain ε_{eq}^{p}

The purpose of the modeling is to determine the stress and strain fields through hydro-mechanical finite element coupled formulation.

The hydro-mechanical finite element coupled formulation takes into account with high precision the factors affecting this area: such as mechanical actions, climate, and water. For the adequate numerical modeling of the behavior of AEH slip, five cuts are made on the unstable zone, through the constructions presented at actual state.

The results of numerical modeling under the effect of hydro-mechanical conditions, introducing the fluctuation of the groundwater effect and a strong precipitation in the transitional flow regime, enabled to study of the evolution of the rupture slope of AEH. The morphology of the equivalent plastic deviatory deformation ε_{eq}^{p} obtained by modeling facilitates the determination of deformation mechanisms within the slope. The analysis shows the shape of the sliding surface which are not similar in all the sections, in the sections AA and BB, we notice a linear sliding and deformation which reaches to the foot of the slope, explained by the strong urbanization along this section. However, the circular sliding surface for the sections C - C, D – D, and EE was observed, which is explained by the heterogeneous geology, and the horizontal permeability of altered schist layers, causing planes of weakness and voids filled with schist alteration product (clay silt of low geotechnical characteristics). ε_{eq}^{p} gives good representations of the state of deformation of the ground, and the results are given in Figs. 8-12. Based from these results, we can consider that the slip of AEH is complex and extended under the influence of the new surface evolution. The sliding surface found by modeling reaches the embankment layer; destructed schist on all the sections with a depth between 20 and 30 m, while on the CC and EE sections the sliding surface even reaches the layer of altered schist and its depth varies between 30 m and 50 m.

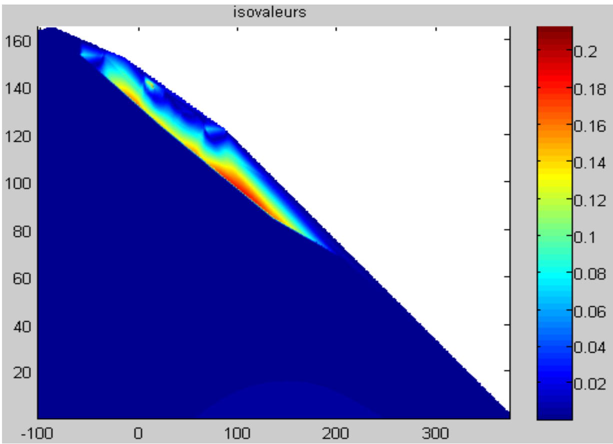

Fig. 8 Equivalent deviatory strain of the section A-A

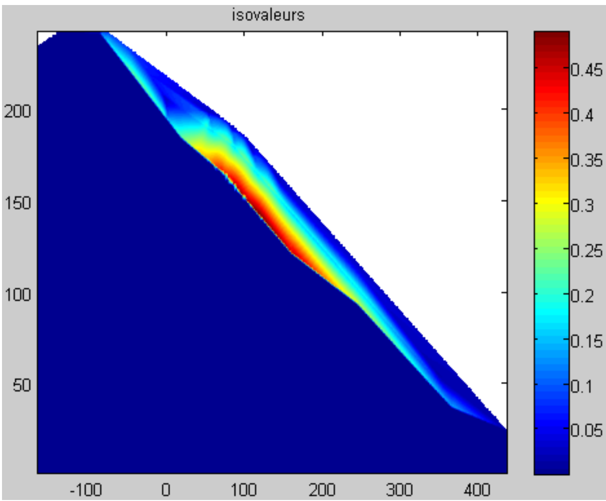

Fig. 9 Equivalent deviatory strain of the section B-B

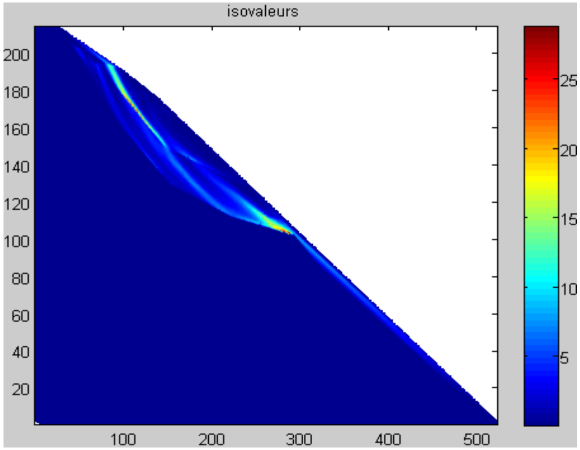

Fig. 10 Equivalent deviatory strain of the section C-C

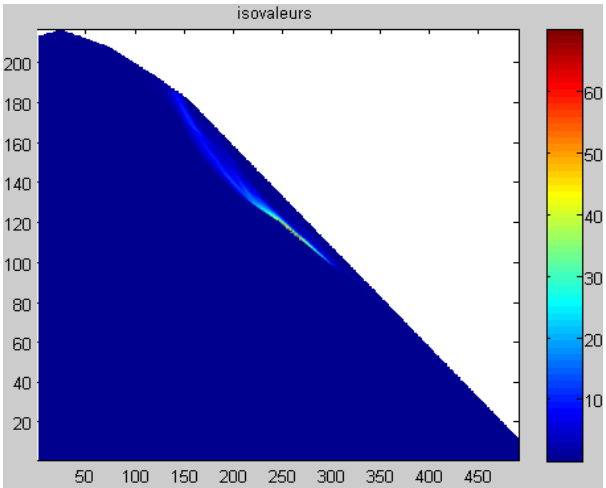

Fig. 11Equivalent deviatory strain of the section D-D

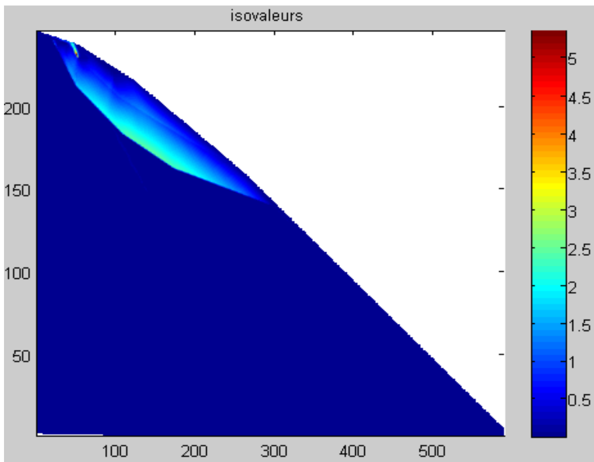

Fig. 12 Equivalent deviatory strain of the section E-E

V. Conclusion

The AEH landslide is still active and characterized by a complex structure. That is why we embarked on a numerical modeling to refine the analysis of the behavior of the slope and its long-term response mode, using in one hand the equivalent deviatory strain and compared them with area measurements in the other hand. These results show that the slope is unstable and confirms the existing of a new slip surface in the southern part of the city. These results are also validated by the topographic monitoring which followed important cinematic on that part of the city. Given the site geology and numerical results, we can also confirm that the propagation direction of the slide is along the natural stratification of shale.

References

[1] L. Djerbal ''Le glissement de terrain d'Ain El Hammam (Algérie) causes et évolution''. Bull EngGeol Environ 71:587–597. 2012. DOI 10.1007/s10064-012-0423-x.

[2] G. Bièvre, U. Kniess, D. Jongmans, E. Pathier, S. Schwartz, C. van Westen, T. Villemin, V. Zumbo,'' control of landslides in lacustrine deposits (Trièves plateau, French western Alps2011'', Geomorphology. 125:214–224. DOI: 10.1016/j.geomorph.2010.09.018.

[3] J. Travelletti, J. Malet, K. Samyn, G. Grandjean, M. Jaboyedoff''Control of landslide retrogression by discontinuities evidences by the integration of airbone- and ground-based geophysical information''.2013 Landslides 10:37–54. DOI: 10.1007/s10346-011-0310-8.

[4] L. Guerriero, J. Coe, P. Revellino, G. Grelle, F. Pinto, F. Guadagno''Influence of slip surface geometry on earth-flow deformation Montaguto earth flow, southern Italy'', 2014, Geomorphology 219:285–305.

[5] ANTEA 2011 Etude du glissement de terrain d'Ain El Hammam par le groupement Hydroenvironnement et TTI DOI: 10.1016/j.geomorph.2014.04.039.

[6] G. Guitard ''ROCHES (Classification) - Roches métamorphiques'' 2015. Encyclopædia Universalis (enligne), URL: http://www.universalis.fr/encyclopedie, accessed October 26, 2016.

[7] Z. Kechidi ''Application des études minéralogiques et géotechniques du schiste au glissement de terrain d'Ain El Hammam. Mémoire Master, université de Tizi-Ouzou, 2010 Algérie, 152 p.

[8] ANRH ''Données de l'Agencenationale de ressourceshydrauliques, Rapport interne''2014.