Land Subsidence and its Consequences in Mashhad City by Integrating Radar Interferometry and Field Measurements

Fahimeh Salehi Moteahd[1], Naser Hafezi Moghaddas[*2], Golamreza Lashkaripour[3], Maryam Dehghani[4]

1. PhD in Engineering Geology, Ferdowsi University of Mashhad
2, 3. Professor of Engineering Geology, Ferdowsi University of Mashhad
4. Associate Professor, Dept. of Civil and Environmental Engineering, School of Engineering, Shiraz University

Extended Abstract

Paper pages (435-462)

Introduction

Mashhad city, the second largest metropolis of Iran, is located in an arid and semi-arid region. Overexploitation of groundwater in Mashhad plain has caused up to 22.5-meter drop in the groundwater level from 1984 to 2013. The groundwater depletion in the unconsolidated aquifer has resulted in subsidence and cracks on the land surface. To determine the land subsidence rate map and the reasons for hot spot subsidence, the latest Envisat images of the ESA Space Agency's Archive for Mashhad plain were used. leveling and GPS data were combined with the radar interferometry results and the annual subsidence rate maps with high precision were obtained. Finally, the geology and soil texture maps of study area are compared to the land subsidence map.

Methods and results

To assess the land subsidence in Mashhad plain three methods of leveling, GPS and Insar are used. Leveling data are available in three profile of ~~of~~ Mashhad-Quchan (BCBD), Mashhad-Kalat (BDBE) and

Mashhad-Sarakhs (BEBN) in two time interval of 1994-2003. The highest rates of subsidence in the BCBD, BDBE and BEBN lines are 7, 3.5 and 8.1 cm/year, respectively. Six permanent GPS stations have been installed in Mashhad plain, among them, NFRD, GOLM and TOUS have recorded the land subsidence, with the highest annual rate of 21.2 cm/year at TOUS Station. The third method applied to assess the history of land subsidence was InSAR radar interferometry which provided the extent and pattern of subsidence in all of the study area. For this, 23 images of the Envisat ASAR are processed during the 05/24/2010 to 06/30/2003 time period. The highest subsidence rate estimated by this method was 32 cm/year in the northwest of Mashhad. In general, two subsidence bowls, in the northwest and south east of Mashhad city are identified. Fig. 1 shows the annual subsidence rate map in Mashhad plain. Using the root-mean-square error (RMSE), the accuracy of the InSAR method was verified with GPS and leveling data.

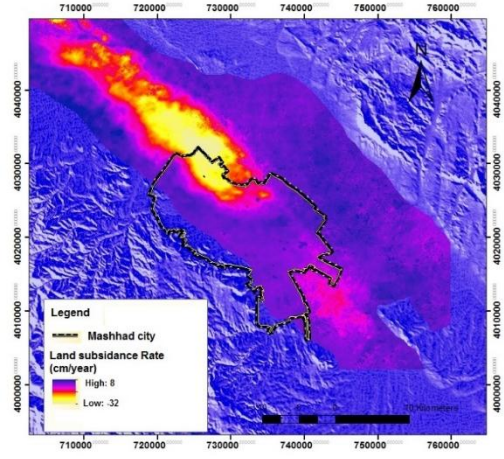

Figure 1: The annual subsidence rate map of Mashhad plain

Discussion

The rate and distribution of land subsidence in Mashhad plain are affected by geological factors such as soil texture, deposit thickness, geological structures and groundwater drawdown. The geological and geophysical studies and exploratory drilling results in the Mashhad Plain

indicate that the bedrock morphology is very rough. The bedrock outcrops in some places while in some other places covered by more than 300 meters alluvial deposits. Generally, by distance from the mountain, alluvium thickness and as a result the likelihood of subsidence would be increased. Mashhad plain is surrounded by the active and quaternary faults in the north and south edges. In the north of Mashhad plain Marly bedrock is uplifted by Tous fault and outcropped in the north of fault. In the south of Mashhad two normal faults have resulted to the increase of alluvium thickness in south and central of Mashhad plain. The change of river pathway also let to deposition of a sequence of the fine-grained and coarse-grained soils in central of plain between Toos and southern branch of South Mashhad fault (F2).

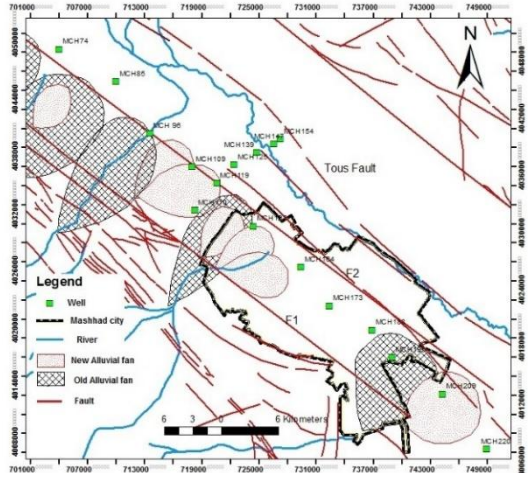

Figure 2: The position of Kashafrood River, alluvial fans, faults and the wells used to draw the cross section

In order to evaluate the subsurface conditions and its effect on the land subsidence, the soil texture are studied using the deep water wells and piezometers log (Figure 2). Fig. 3 shows the longitudinal section (northwest to southeast) of the area. As it can be observed, the soil texture includes of alternation of fine and coarse grains layers (Figs. 4). In this condition, sandy soils help to shortening the drain path of clayey layers and leads to

acceleration of the consolidation. The average rate of annual subsidence in the area is 14 cm for one meter of drop in the groundwater level.

Nowadays, in the urban area, due to the urban sewage waters, there is a rising of groundwater level. Therefore, no land subsidence has occurred in the central parts of the city. It is expected by completion of urban sewage network about 62 million cubic meters of sewage water will be eliminated from the aquifer recharge, which will cause a notable drop in the groundwater level and prominent land subsidence in specific area of the city. Considering the geological conditions and the operation of the existing faults, it is expected that in the case of groundwater drop, no significant subsidence will occur in south of the F2 fault, due to the decrease in the alluvium thickness and to the coarse texture of the soil. But in the northern and northeastern parts of the city, which are located between F2 and the Tous faults, high rate of land subsidence is expected.

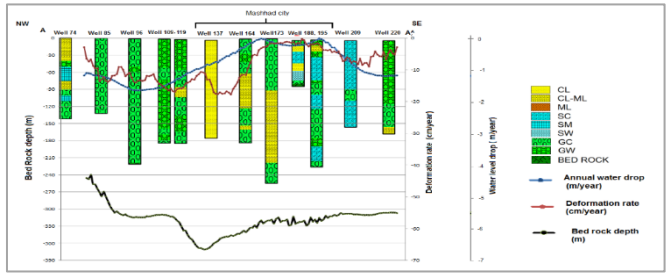

Figure 3: The longitudinal section of soil texture and the annual average rate of land subsidence and groundwater level drop

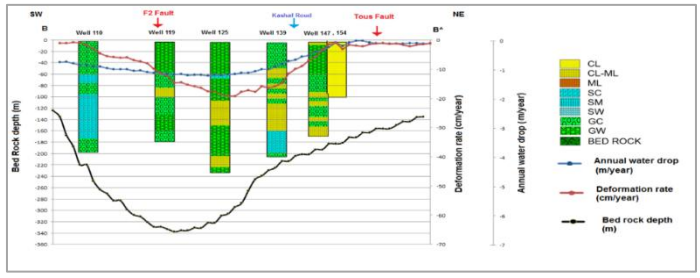

Figure 4: The cross section of soil texture and the annual average rate of land subsidence and groundwater level drop

Conclusions

Using the radar interferometry processing, the highest annual rate of subsidence in Mashhad plain is about 32 cm/year. Land subsidence in Mashhad plain has an increasing trend and the geological conditions have a critical role in the subsidence rate and its pattern. Generally, soil texture near the mountain area in South is coarse and grain size decreases toward the center of the plain. But because the outcrop of Marly formation in the north slopes, soil texture is mainly fine grains. In the center of Mashhad plain soil texture constituted of fine and coarse grains which are converted together as inter fingering facieses, which have a critical role in decreasing of the consolidation time and increasing the land subsidence rate. It is predicted by complimenting of the urban wastewater network, the groundwater level will be dropped in the city area and the northwest and southeast subsidence ellipsoids which already can be seen will be connected together. Therefore, the area between F2 and Toos faults, will be shown the highest rate of subsidence, due to high thickness and fine-grained soil texture.

Keywords: Land subsidence; Interferometric Synthetic Aperture Radar (InSAR); Groundwater decline; Leveling; Mashhad City.

*Corresponding Author: nhafezi@um.ac.ir