Evaluation of Groundwater Management Techniques for the City of Mashhad

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Abstract

In recent years the rise of groundwater level in some regions of Mashhad, attributed to the water transfer from the surrounding dams has caused complications in many projects. Groundwater in Mashhad is mainly charged from Binalood Mountain in addition to absorbing wells traditionally used as an effluent disposal method. However, the balance of groundwater has been further tipped by decommissioning of upstream suburban water wells, having been replaced by the water transferred from Dousti dam. Obviously, inbound groundwater diversion methods and/or regional drainage projects are needed to compensate the extra inflow. One of the successful methods for groundwater diversion is appropriately positioned grout curtains in aquifers, acting as a subsurface dam. River and canal engineering projects aimed at prevention of surface runoff infiltration, as well as re-commissioning of wells, would also positively affect the problem. In this study, the effectiveness of the aforementioned methods for groundwater management is studied and based on the available data tentative proposals are made as to the most effective methods.

Keywords: Mashhad, groundwater management, subsurface dams.

1. INTRODUCTION

Typically, the major concern in groundwater for water resource management engineers is a decline in groundwater levels [1]. But today rise in groundwater levels has become a major concern all over the world which has been reported in most cities around the world [2, 3]. In Iran, we can mention the cities of Mashhad, Kerman, southern Tehran and Sabzevar. As direct groundwater recharge is reduced by the development of urbanization, new sources for recharging aquifers, including leakage from water pipes, sewage, absorption wells and other waterways, are created. The effects of these changes often increase groundwater recharge than pre-urbanization. The rate of increase in groundwater level in arid regions and populated cities where drinking water is usually supplied from other resources is significant [4].

If the groundwater level rising continues, it may have a geotechnical effect on the structures [5]. The rising water level causes serious problems for existing structures as well as new constructions. The problems for new constructions include water entering the construction sites, increased maintenance costs for trenches and the system supporting structure for the temporary stabilization of trenches. In the existing structures, the rise in groundwater level and an increase in the moisture content of the soil will reduce the soil's resistance, increase the liquefaction potential, increase the risk of soil compaction due to the water compression, the increase in the soil corrosivity potential and the deterioration of concrete and metal components [6]. In this study, we will show the rise in groundwater levels, describe its problems and finally, we will present solutions to deal with these problems or mitigate their effects.

2. SOIL TEXTURE OF MASHHAD CITY

In general, sediments of Mashhad city include sedimentary deposits, flood plains and conifers. The maximum thickness of sediments in the center of the Mashhad plain is more than 250 meters. The thickness of sediments is reduced to the southern and northern slopes (Fig. 1) [8].

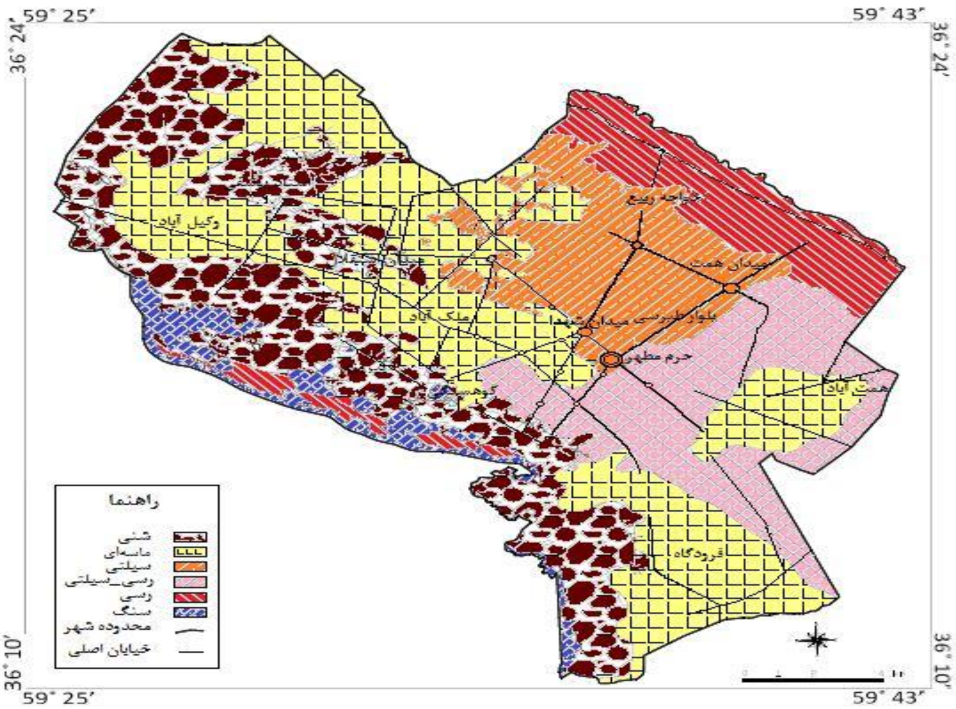

Figure1. Map of Soil texture of Mashhad city [8].

3. LOCALIZED RISING OF GROUNDWATER WATER LEVEL IN MASHHAD

In recent years, Dousti Dam has been one of the most important Mashhad's sources of drinking water. In this way, 500 million cubic meters of the outflow of the dam enter into the Mashhad watershed. With the arrival of this volume of water, the drinking water wells in the city were turned off. On the other hand, the development of some urban infrastructures such as the sewer collecting network did not construct along with other urban developments. As a consequence, the water entering the aquifer has caused the localized water level rises, especially in the central areas of the city, which imposes some problems for other urban development [9].

Ghandahari et al. (2014), showed that there are four periods of groundwater water level changes during the period of 1985 to 2013, by drawing the hydrograph of the existing piezometers in the city center (Fig.2). In general, groundwater level decreased from 1985 to 1991, increased from 1991 to 2001 and again decreased until 2008 and then increased. From 2008 to present, despite the drought, a rise in groundwater level is observed. The groundwater level has been rise 36.23 meters in 68 months (an average monthly increase of 1.53 meters). Therefore, it can be concluded that the main factors of the rise in groundwater level are the entrance of the Dusti dam outflow into the watershed and the lack of utilization of drinking water wells [9].

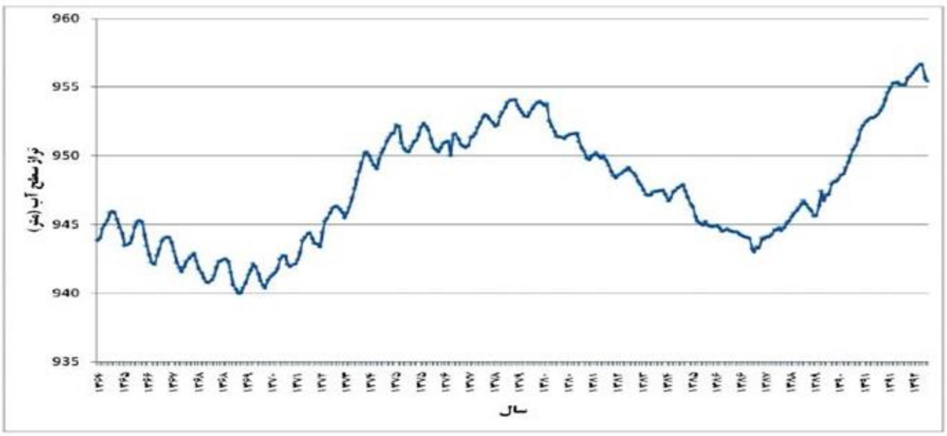

Figure 2. Hydrograph of the piezometers in the city center.

In general, the reasons for the localized rising of groundwater water level in Mashhad are:

1. Transferring more than 500 million cubic meters of water out of the basin (Dusti dam) into a small watershed for drinking water and turning off the drinking water wells in the Mashhad city, simultaneously [9].
2. Numerous Qantas that drain groundwater from different areas to the central basin of Mashhad [7].
3. The existence of Golestan artificial recharge in the upstream basin of the catchment area and on the Qantas route, hence transfer water to the central basin [12].
4. Consolidation of soil due to groundwater withdrawal, reduction of soil storage capacity, and consequently the increase in the velocity of entry water rising from absorption wells [9].
5. The existence of clay layers with a low depth (up to 40 meters) below Mashhad creates a shallow aquifer [9].

4. PROBLEMS DUE TO LOCALIZED RISING OF GROUNDWATER LEVEL IN MASHHAD

The rising water level causes serious problems for existing structures as well as new constructions. The problems for new constructions include water entering the construction sites, increased maintenance costs for trenches and the system supporting structure for the temporary stabilization of trenches (Fig. 3). In the existing structures, the rise in groundwater level and an increase in the moisture content of the soil will reduce the soil's resistance, increase the liquefaction potential, increase the risk of soil compaction due to the water compression, the increase in the soil corrosivity potential and the deterioration of concrete and metal components [10].

Figure 3. Water entering the construction sites.

I. Reduction in bearing capacity [11]
II. Reduction in soil stiffness and/or Collapsibility phenomenon [12]
III. Degradation and corrosion of structures [13]
IV. Liquefaction
V. Sewage Infiltration to groundwater

5. SOLUTIONS FOR LOWERING GROUNDWATER LEVEL

I. Aquifers management and prevention of excessive recharging of the aquifer, through the construction and development of sewage and surface water collection networks (completion and development of the energy tunnel in the distressed area of Mashhad city) (Fig. 4).

II. Water supply management from the Dousti Dam and the water wells in the northwest of Mashhad (Ghasem Abad area), which is no longer withdrawn from them.

III. Construction of underground dams in the north, northwest and southwest areas, pumping of stored water behind these dams into canals and rivers inside the city and eventually, transferring the water to the Kashafroud river as a natural drainage area.

Figure 4. Energy tunnel in the distressed area of Mashhad city.

From the above, we will explain the underground dam.

6. THE UNDERGROUND DAM

I. What is underground dam?

A facility that dams up groundwater flow, stores in the pores of the stratum and uses groundwater in a sustainable way. Furthermore, a facility for preventing saltwater intrusion is also included to definition of the underground dam. In a wide sense, it is called as underground dam including reservoir area (Fig. 5). Underground dam have no huge "Tank" under the ground, generally have a lot of porosity in the aquifer (underground). In other words, underground dam reserves the groundwater in "hard" porous sponges [14 and 15].

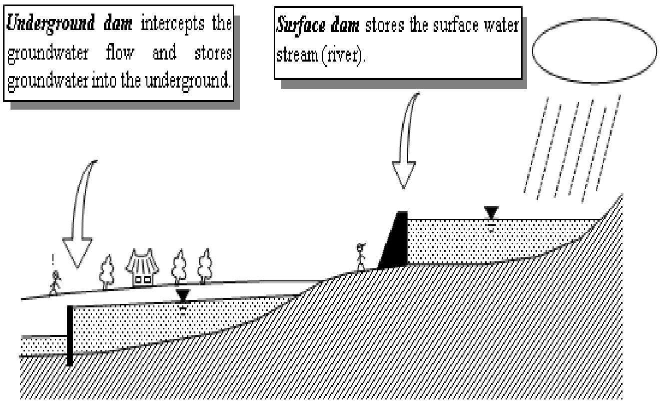

Figure 5. Scheme of surface dam and underground dam [14].

II. Types of Underground Dams

i. Classification by dam purpose.
ii. Classification by construction method.
iii. Classification by the reservoir type.

i. Classification by dam purpose.

a) Dam up type (Storage type, Run-off control type): This dam type is planned to store groundwater. The reservoir, which dams up groundwater and regulates its discharge, accordingly increases the groundwater level and allows stable intake of groundwater [14 and 15] (Fig. 6).

b) Saltwater intrusion prevention type: This dam type is planned to prevent intrusion of saltwater into the groundwater and to protect available water resources. The reservoir unconditionally allows groundwater pumping and the resultant adjustment of the groundwater level [14 and 15] (Fig. 6).

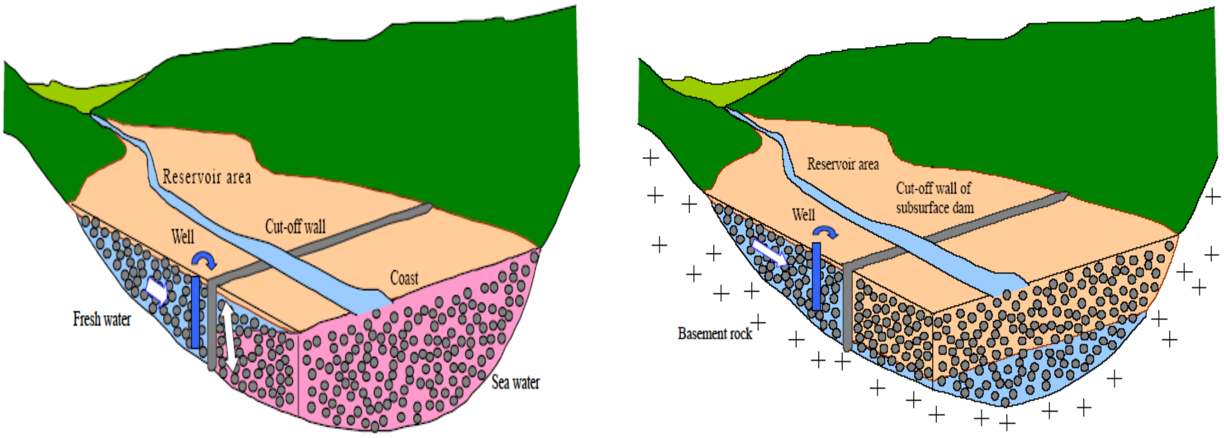

Figure 6. Dam up type (storage type), Saltwater intrusion prevention type [14].

ii. Classification by construction method.

a) Ground improvement method (grouting method): In general, is applied by foundation improvement of the surface dam, using an injection of cement milk under the ground and hardening the milk, and so constructing the impermeable barrier (grout curtain). This method is applied to the underground dam in small scale [14 and 15].

b) Impermeable body driving method: This method is to construct a dam body by driving steel sheet pile (or concrete sheet pile). This method is used for shallow unconsolidated layer [14 and 15].

c) Diaphragm wall method: Diaphragm wall method is applied to the underground dam in large scale. Among of the several types of diaphragm method used for underground dam construction, (Soil Mixing Wall method) [14 and 15].

iii. Classification by the reservoir type.

a) Fully subsurface storage type: This dam type is an ordinary case of underground dam and reservoir is not visible directly [14 and 15].

b) Partially surface storage type: This dam type has functions not only to reserve groundwater but also to store surface water on the ground in the reservoir area [14 and 15].

a) Surface dam hybrid type: At the surface dam, reservoir water is stored in the ground in addition to on the ground by the effectiveness of the water-tightness barrier, which is created by the foundation treatment such as grouting works [14 and 15].

7. Requested natural conditions for underground dam

a) Excellent storage aquifer

An aquifer with large effective porosity and hydraulic conductivity must be available in the planned area.

a) Impermeable basement

The basement stratum forming the reservoir floor and side boundaries must be relatively watertight so as to form efficient groundwater reservoir.

a) Sufficient recharge to the reservoir area

Sufficient and appropriate groundwater recharge must be available in the reservoir area of the underground dam. Normally, high precipitation and infiltration will be required corresponding to the planned amount of storing water [14 and 15].

8. Criteria for choosing dam site

- Sandy soil (images of river bed and surface information).
- Less salt content.
- Large average annual flow rates (annual rainfall data is the measure).

- Land gradient <5% (Topography and DEM).
- Less drainage density (WMS calculation).
- Less evaporation rate (meteorological data).
- Bedrock not too deep (experience 20-70 m, geological maps, geophysics, etc.).
- Do not build on fractured rocks or large boulders to prevent seepage.
- Build on solid bedrocks instead or 1 meter in the solid and impermeable soil [14 and 15].

9. CONCLUSIONS

The rise of the groundwater level in some parts of the Mashhad over the past few years has caused disturbances in some construction projects. Over the past decades, factors such as water transfer from the surrounding dams, waste water disposal through absorbing wells and the decommissioning of upstream wells have led to an increase in the water balance of the region.

One of the successful methods in groundwater diversion, which can be a suitable solution for diversion of the excess inflow to the north and northwest of Mashhad is subsurface dams. also, river engineering projects in Binalood Mountain and pumping and water transfer to Kashafroud river (as natural drainage of the area) can be complementary to this action.

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