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Research Article

EVALUATION OF DEEP IRRIGATION AND LEACHING WATER IN AQUIFER RECHARGE USING MOD FLOW MODEL.

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ABSTRACT
In recent years the Masileh plain aquifer due to excessive withdrawal of groundwater for agriculture is faced with a great loss, which causes intrusion of salt water into the groundwater resources of the region, and has caused critical quantitative and qualitative status of aquifer. Due to this condition there is a need for more accurate assessment of the condition of the aquifer and practical and effective solutions in order to maintain and strengthen this water source is inevitable. The present article reviews the performance of the two most popular methods of feeding the aquifers. And through modeling of groundwater a comparison between the results of implementation of each of these conditions has been done for Masileh aquifer. In this study, the collection of data needed for modeling groundwater and completing and correcting deficiencies in the existing statistical, mathematical model of Masileh aquifer was developed using Mod Flow software. Then the model was calibrated by changing the input parameters in the logical range and comparing contour lines of the computational water level and the observed water level of piezometer wells. Finally, to ensure the accuracy of the calibrated parameters, the model was implemented for a year and the observations were verified at the end of the period of correction survey. After ensuring the accuracy of the mathematical model, there are now two options to improve the quantity and quality of groundwater in the studied area. They were evaluated and the results of the implementation and the effect of them on future conditions of the aquifer in comparison to the average long-term hydrograph were measured. The results show that artificial feeding compared to deep irrigation with leaching has better effects on the qualitative condition of aquifer in the long term. However, water levels will continue to maintain its bearish trend.

Keywords: *Deep Irrigation, Feeding, Modflow, Model*

INTRODUCTION
As a general definition, the whole water in the subsurface of the earth at a pressure equal to or greater than the atmospheric pressure is called groundwater. More than 30% of the world's freshwater, as well as roughly 97% of the water used for drinking are provided from these resources. With the rapidly growing demand for a fixed quantity of water in the world, water will be a scarce commodity as time goes by and it will increase competition for extraction. In this regard, groundwater resources as well as a large supply of fresh water in the world won't be far above the competition. For this reason, the need for better understanding of the characteristics of the aquifer and how they respond to environmental actions with the aim of predicting the future seems necessary. The results of this study, in addition to clarifying the nature, and the current situation of ground water; it can be used as a program to control the consumption and utilization of the aquifer in the future.
The present condition of the Masileh aquifer with an average annual decline of nearly 1 m and intrusion of salt water of salt water lake caused numerous problems. And it seems the current trend continues the next few years to practice their efficiency will lose its importance as the most important source of water available to farmers.
So there is no choice due to various strategies to strengthen the aquifer recharge water source. In this paper we evaluate the effectiveness of different methods of recharging in the studied area through modeling aquifer. In the field of mathematical modeling of aquifers, numerous studies have been conducted around the world. In each of these studies regarding the particular circumstances of different

criteria for accepting the results is intended. In this study we can point out the studies done by Bradly (2006), Ramireddygari *et al.,* (2008) and Reeve *et al.,* (2011).

Bradly through using a simulation model and data relating to fluctuations in the water table, evaluated adjusting the parameters of specific yield and hydraulic conductivity, the effects of water level in the aquifer to recharge from rainfall and infiltration, and achieved satisfactory results Jiao and Lerner (2008) in their simulation model through dividing the aquifer into distinct regions, and using analysis of sensitivity to measure the effect of physical parameters on the aquifer, presented relatively close estimation of measured values of the parameters.

To evaluate the interaction of rivers and aquifers, Ramireddygari *et al.,* (2008) through combining the two models of surface and groundwater (Mod flow), and reported the effect of irrigation structures and water basin on the level of groundwater and stream flow. The estimation of these effects was well done by the simulation model.

Reeve *et al.,* (2011) in a regional study through using the model of Modflow calculated the flow of groundwater on the aquifer water balance related to the lake.

Gieske and Miranzadeh (2002) evaluated the changes in groundwater levels in the southern region of Lanjanat, in a sub-basin of Zayandehrood river to determine the components of the water balance.

Their regional groundwater modeling and simulation using concluded that The overall supply of 267 million cubic meters per year and the total usage of 192 million cubic meters per year (including wells, springs and aqueducts) and drainage of 76 million cubic meters per year into Zayandehrood river, the water balance in the aquifer will be in balance.

Thorley *et al.,* (2005) through using the software Modflow modeled the groundwater of Chris George city in New Zealand. For modeling they used monthly data of 157 wells supplying drinking water for the city. To estimate the hydraulic conductivity parameters and the amount of feeding they used the reverse modeling method and Pest software. Finally, with software Modpath and the data of 31 selected wells, simulated groundwater contours. Rahnama and Kazemiazar (2006) simulated the groundwater of Rafsanjan Plain using the mudflow software and examined the effect of decreasing of groundwater level on the subsidence of the land in this plain.

MATERIALS AND METHODS

Describing the Package Madflow Software

It was first published in August 1994. It is complete software with very high graphics capability that can be used very easily for specific applications in simulation of modeling groundwater flow and transporting contaminants. This software is designed to increase profitability and reduces the complexity of modeling, such as the complexity of the models with three-dimensional groundwater flow and transporting contaminant. The entire program is divided into three modules, the input module, implementation module and output module.

The Input Module

The Implementation Module

Conditions (stable or unstable) and in this module it runs through selecting one of the various methods of solving differential equations.

Output Module

In this part of the results of the model will be shown graphically.

This section contains various display outputs such as the contours of the ground water, velocity vectors, the result of balance calculation, arid regions and.... Also in this section curves drop-time and water pressure-Time for each of the observed wells are drown.

The General Characteristics of the Studied Area

Geographical Location of the Studied Area

Masileh plain with an area of about 94 sq. km is one of the four plains in the studied area of Qom, that starts from high altitude in the northeast of Qom and spreads to the southeast. Groundwater is used as the most important source of drinking and agriculture purposes. Aquifer with an average depth of 20 meters is responsible for supplying the need irrigation requirements of the agriculture in the studied area. The location of the studied area is shown in Figure 2.

Weather and Climatology

The studied area of Masileh plain climatically is located in the cold arid region. According to statistics synoptic station of Qom, the average annual temperature of over 18 ° C, which fluctuates from more than 31 ° C in July to less than 6 ° C in January. The average annual rainfall in the studied area is about 170 mm and the average relative humidity is about 43 percent.

Hydrogeology

Providing Hydrograph for Mean of Masileh aquifer

In order to determine the groundwater level fluctuations during the period, as well as the underground water storage, unit hydrograph was drawn. To do this, with using piezometers which had complete measurement period we tried to provide Tyson of the plain and then through calculating the area of each zone, the unit hydrograph of Masileh plain was drawn (Figure 1). As can be seen an average drop of aquifer is estimated about 10.5 meters in a statistical period (9/0 meters per year). Increasing the number of wells in Masileh plain and the reduction of the flow of Gharachai River are the most important reasons for the reduction of groundwater levels.

The Groundwater Level

In order to study the direction of groundwater and determine recharge and discharge areas of aquifers, groundwater counters were prepared at the beginning of the modeling (Figure 2). Regarding this map it can be stated the direction of stream line of water is from the northwest to the southeast and east of the plain. In general, northern parts are the inputs and the Southern and Eastern regions are the outputs for groundwater of the plain.

Preparing a Mathematical Model for Masileh Aquifer

Using computer models of underground water in recent decades as a cheap and fast way of movement, water balance management and exploitation of groundwater has been significantly paid attention. Among the models that have great potential in studying the groundwater is McDonald's and Harbag three-dimensional finite difference model named Modflow that was in 1994. Modflow is a three-dimensional model of unsteady flow in saturated porous, unsaturated, non-homogeneous and non-isotropic media. This model is widely used by researchers around the world.

Entering the Parameters and Running the Model

Using the results of statistical operations carried out on the groundwater resources of the region and the use of data on wells, piezometer wells. And pumping tests, also regarding the characteristics of the aquifer in the early stages, essential parameters for modeling such as stone floor and the surface layer of the aquifer, depletion of ground water through wells, springs and aqueducts, hydrodynamic coefficients of aquifer and ... were entered the model and mathematical model of plain water for the years 2003 to 2004 was conducted. Figure 3 shows the observed and calculated values of piezometers wells in the first implementation of the model.

Calibration

Calibration is the process of finding a set of boundary conditions, Stresses that the results of the hydrogeological parameters that its obtained results, very close to the hydraulic load and flow field measurements. Trial and error in the calibration of groundwater models is one of the oldest and at the same time the most effective way. In this method parameters are entered to the model as inputs, after running the model between the observed and calculated water levels a comparison will be performed. If significant differences exist between these two levels, the expert will correct the parameter, then the corrected parameter will be given to, and the model will be run again. This is repeated until acceptable results are obtained. Mathematical model of the Masileh aquifer was calibrated using trial and error method for water years 2003-2004.

Validation

The accuracy of the model is confirmed when it is proven that there is the ability of the model to predict in the acceptable limits of independent test from calibrated data. After calibration, the validation of model

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is used to determine the correct or incorrect combination of data. In the verification stage if the model can simulate the events of the period other than the calibration period, the combination of parameters used is correct. Otherwise, the model is not acceptable and the combination of used parameters is not correct. In order to verify the mathematical model of the statistics of 2005-2006 was used. The model was run for the new water year and the obtained water levels with the observed water levels in the piezometers were compared. Figure 4 shows the fitted values of calculated and observed water levels of piezometers at the end of the validation period.

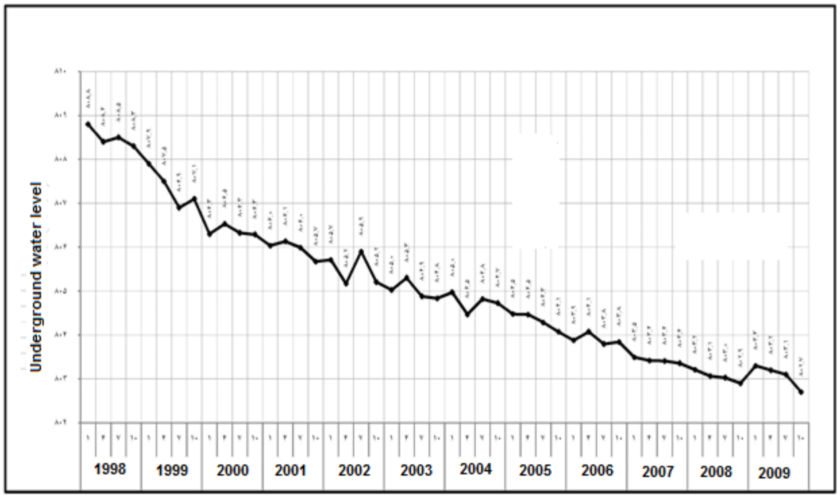

Figure 1: The mean hydrograph of Masileh aquifer

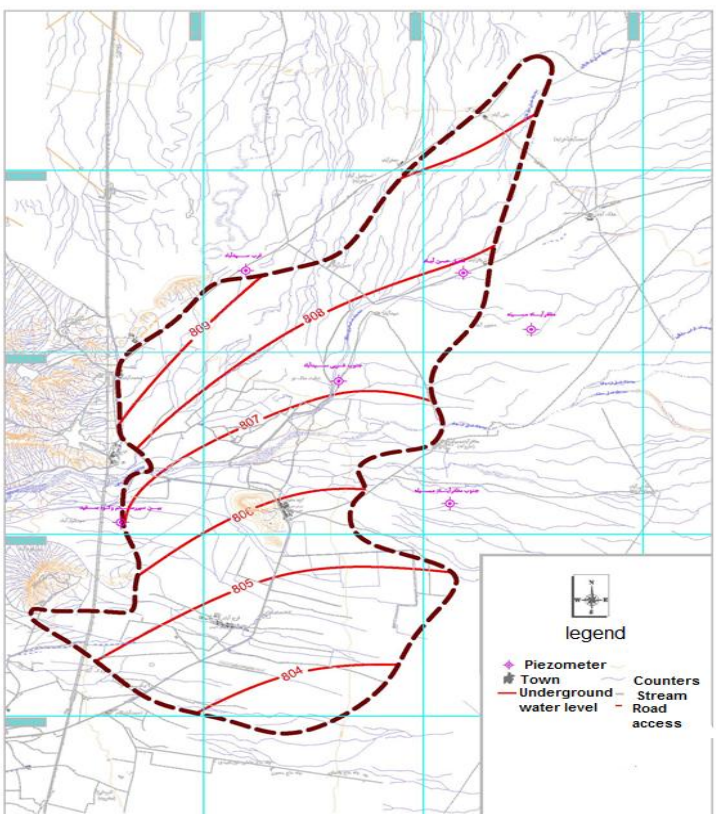

Figure 2: Location of Masileh aquifer and the underground water level of in 1999

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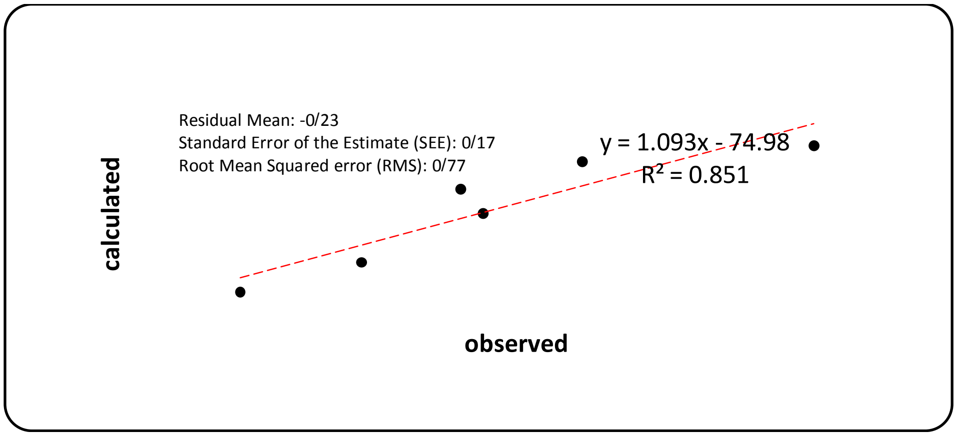

Figure 3: Fitted values of calculated and observed amounts in the first time when the model ran

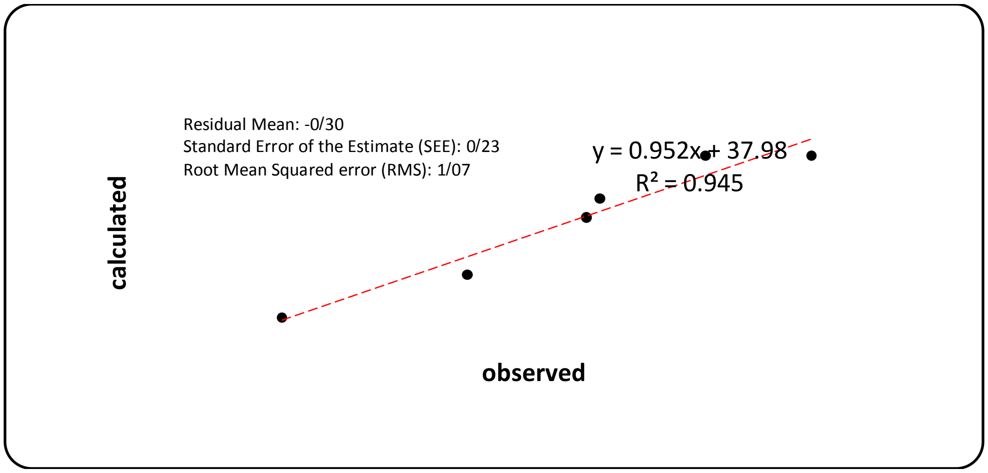

Figure 4: Fitness values of observed and calculated amounts at the end of validation period

Forecast

After the validating the model and ensuring that the aquifer parameters are correctly estimated, it can be used to evaluate the performance of each of the studied options in the form of the transfer of excess surface water and wastewater of Tehran province to Masileh plain design to improve the quantity and quality of aquifer requirements. In the following report on the objectives of each of the options is presented. And the reaction of aquifer and the implementation of the options are analyzed by mapping hydrograph of groundwater levels in the normal situation and assuming given the implementation of option is investigated.

Transferring surface water of Tehran aims to Masileh plain to meet the needs of the agricultural needs and improving the quality and quantity of aquifer by feeding excess water is being studied. Two options were considered in the plan for recharging aquifer the following practical results of the implementation of model is presented if it will be practical.

A) Artificial recharge of aquifers through absorption wells:

In this option due to the volume of water intended for feeding and the table of temporal distribution of excess water (Table 1), 70 absorbed wells in different parts of the aquifer (generally in the range of agriculture) has been predicted that the drilling area of these wells is shown in Figure 5. Through running mudflow model and regarding mentioned wells in an area of 300 ha of agricultural lands, results in the form of long term mean of groundwater hydrograph were compared (Figure 6). As you can see the average level of the aquifer by performing choices about 4.5 meters in the 10-year-old period compared to the normal situation will rise.

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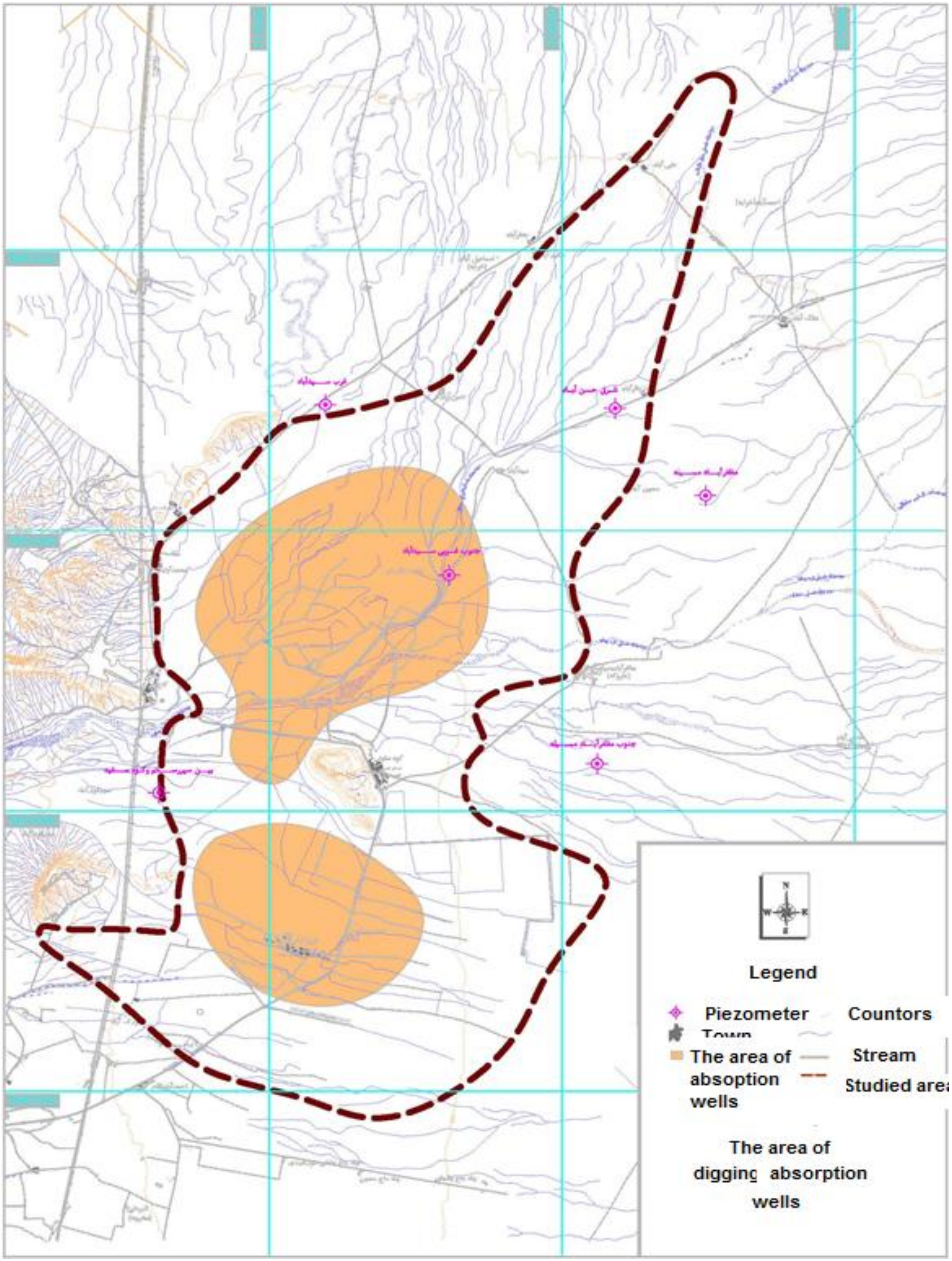
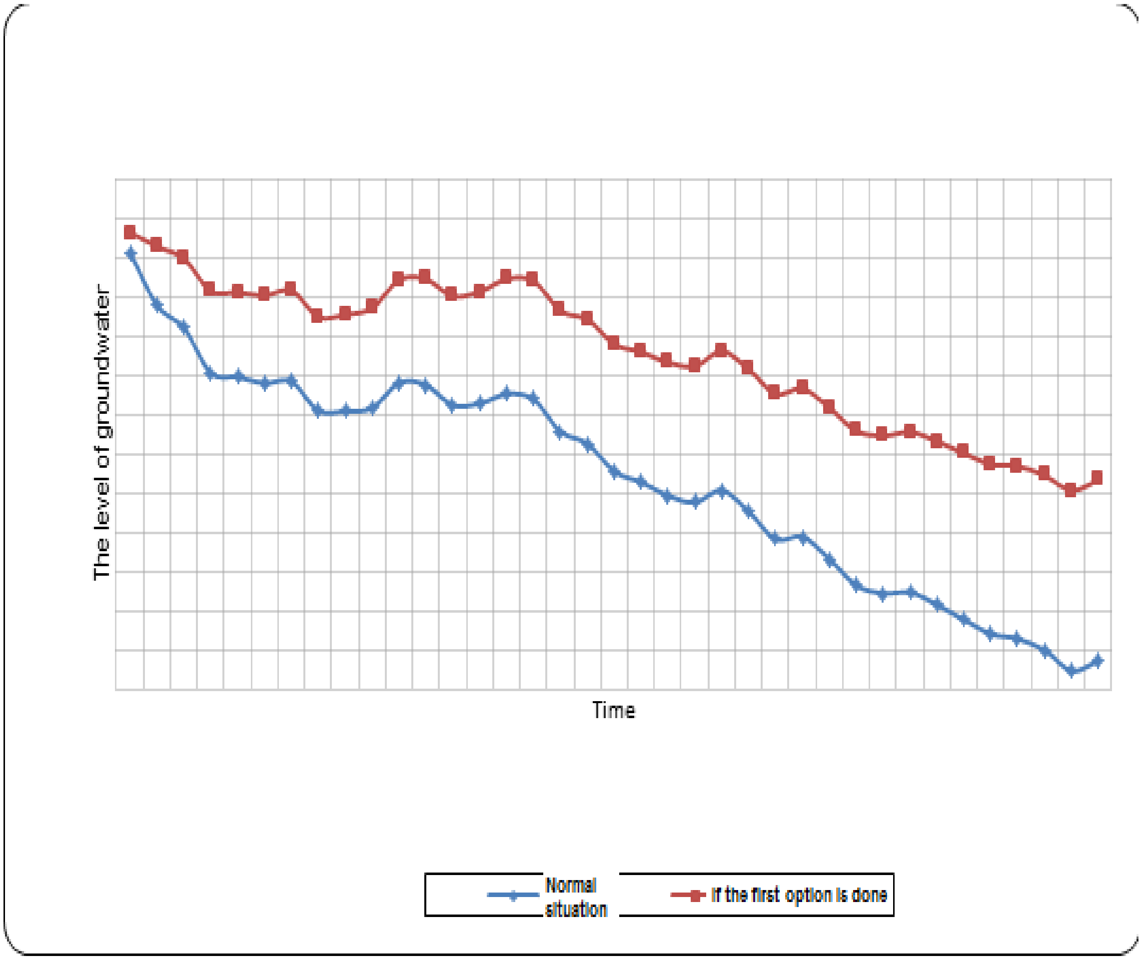


Figure 5: The area of digging the absorption wells

Table 1: Distribution of surplus water for recharging Masileh aquifer (million cubic meters)

Annual	Mar	Feb	Jan	Dec	Nov	Oct	Sept	Aug	July	June	May	Apr
37.4	0.3	2.9	10.9	17.7	0.0	0.0	0.0	0.0	0.0	0.1	5.5	0.0



Figure

B) Natural feeding by leaching and deep irrigation:
Regarding the transition time distribution of water which are available in November, December, January and February, we can determine how to utilize the capacity of the transferred water.

In May agricultural lands of Masileh plain are cultivated. Considering the fact that at this time most of the crops are in different stages of their growth, and are so sensitive to soil saturated conditions, the possibility to recharge the aquifer in this month is considered as part of the leaching requirement, for agricultural lands with a deep irrigation and leaching of gardens and the infiltration from the floor of Gharachay River. By taking the average of 35% leaching for irrigation agricultural lands and a deep irrigation with leaching in an area of 800 ha of gardens (With a depth of about 25 cm) the surplus water of May can be entered to the aquifer. In the months of December and January with regard to 3 times the leaching of agricultural lands (with a depth of about 30 cm) that twice takes place in the beginning and the end of December and once in January the mentioned area and taking into account the influence of the river bed, and leakage from transmission and distribution canals, and subtracting the amount of evaporation of water in each of the above steps, excess water can be transferred to spend on feeding aquifer in these month. In February, the surplus water can be transferred through a leaching in a range of area of approximately 900 ha of farm and garden area alternately selected each year, will be spent on aquifer recharge.

Running the Modflow model according to the above description, the practical results of the second option on the Masileh aquifer, is shown in the figure below (Figure 7). The average balance of the aquifer in the implementation of natural feeding will climb to about 3 meters in 10 years.

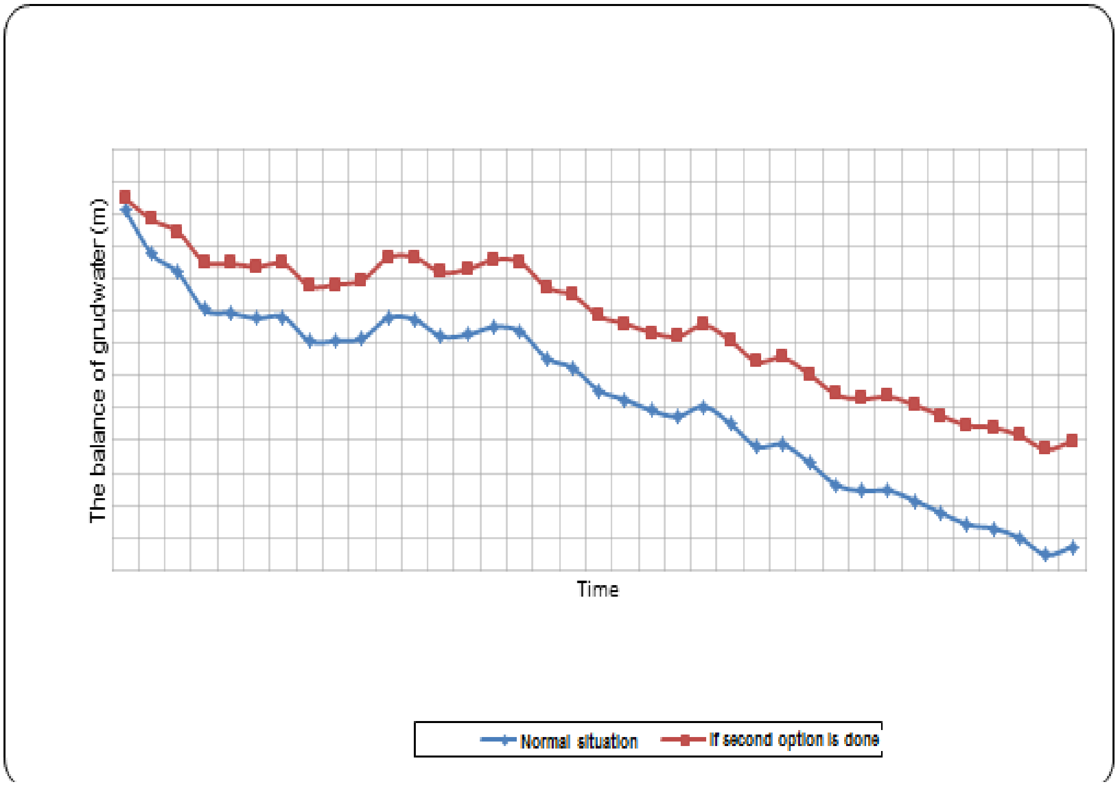


Figure 7: Comparing the hydrograph of mean of Masileh aquifer under normal conditions and in the implementation of the second option

CONCLUSION

To prepare and study the mathematical model of aquifer of Masileh plain the following results were obtained:

1- One of the aims of mathematical model is to evaluate the accuracy of data and information. After preparing the model, it was determined that the existing data has the following defects.

- Depth to bedrock at a depth of some Sondage Geoelectric exploitation wells that are located near don't have concordance.
- The network of drilled piezometers wells don't have a good scope and distribution in the plain and some of them have statistical defects.
- Pumping tests don't have a high accuracy and is not enough to determine the hydrodynamic coefficients of aquifer.
- The annual discharge volume for the wells in Masileh plain is from the inventory of groundwater resources that have been calculated in 2003, does not conform to reality. The inventory due to the neglect of illegal wells and the lack of precision in the measurement of flow rate wells don't have a high credit rating.

2. Regarding the possible scenario planning and evaluation of the future status of the aquifer following results were obtained:

- Implementation of artificial recharge of aquifers will be better in the future.
- In the case of the implementation of each of the options, the groundwater levels still will decline that further measures should be taken in this regard.

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