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European Journal of Experimental Biology, 2013, 3(3):706-711

ISSN: 2248 –9215
CODEN (USA): EJEBAU

Agriculture water supply in semi-arid zone by underground dams

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ABSTRACT

The increase industrial and agricultural development, caused by the population growth on one hand and the limited amount of water resources available on the other hand has caused the ground waters to be considered as a valuable water supply more than ever. The lack of rainfall in the past few years, followed by drought has increased the unmethodical usage of these water resources in Iran as well as in other parts of the world more than ever, which ultimately has resulted in a severe drop in the level of waters available within the aquifers that are located beneath many plains. This has caused problems in agricultural sector and other manufacturing sections in these areas. One solution that has been suggested for supplying water (usually in a small scale) in dry and arid lands where there is no access to conventional water sources such as wells and permanent rivers, is by using subterranean currents in the dried bed of rivers which are controlled by a water-sealing wall (underground dam) and would eventually be exploited afterwards. Exploiting the water resources accumulated in the reservoir created by a dam for drinking, agriculture and industry are considered as one of the most important goals for constructing these dams in arid and semi-arid regions. As we examine the utilization process of exploiting underground water in a dried river bed, by using an underground dam, constructed along the dessert borders, we would also describe the management plan of water, stored in the underground dam's reservoir, for preserving and developing the level of cultivation and horticultural lands, by using a mathematical model.

Key words: Underground dam; underground water; MODFLOW; simulation; Koohzar

INTRODUCTION

The areas, where surface water does not exist or is useless, the underground water is considered as the most important source of water for securing the water needs of human communities. Currently, about a third of the world's population depends on underground water, and more than 70 percent of the underground water is used in agriculture. The developments in agriculture and industry has led to the increase in the water exploitation from underground water resources in a way that these unmethodical exploitations from underground water resources has resulted to the feeding rate of aquifers not to answer the level of water exploitation and the ultimately the groundwater levels to drop. These actions have resulted in a series of problems including: dryness of water wells, water quality degradation, reduced river flows and lake waters, increased pumping costs, water extraction and ground subsidence. Drought, in recent years, has showed its effects on the agricultural section. Given the importance of this section and its fundamental role in providing food security to the community, we should consider that: despite the shortage of water and water crisis, how the development of agricultural section should be achieved Iran has many villages, which are scattered around the country. These villages served as the food providers for cities, in the past, and their income was mainly based on agriculture; when the population exceeded their production potency, their economic thrive eventually fell and became forgotten. The other basic issue of these scattered communities is the provision of their water needs, which lack directs access to the surface and underground water; also, due to the declining trend of rainfall in their living areas, the farmers are in danger of losing their agricultural land and livestock that may eventually turn into non-productive and useless elements (Telmer K and Best M,2004).

Resolving the issues in these regions require thus, using simple and inexpensive ways of providing water for these areas, with the help and cooperation of the local people themselves in their required and designated areas [13]. The aim of this study is to evaluate the efficiency and the method of exploiting underground water in the dried bed of the Zar river, by using an underground Dam by the same name, and offering the management program of exploiting the water stored in the underground Dam's reservoir with the aim of developing agricultural and horticultural lands under cultivation by using a mathematical method. By examining the related history of exploiting subterranean waters, by using the underground dams in various sources and conducted searches, it was shown that underground dams in rural areas, located in developing countries with dry climate have more advantages in comparison with the surface dams, particularly when they reduce the possible risk of contamination and the evaporation of water [7].The history of these dams, in Europe, has been attributed to the times of the Roman Empire (Nilsson A, 1988). Huge underground dams were mainly designed for the increased access to the subterranean water for irrigation in the regions of northern Africa, particularly in Morocco and Algeria [1 and 11]. The importance of underground dams in providing water to the dry region of Neroset, in Brazil, has been studied by "Pompea Dos Santos, Fringipani, Leite, Oliviera, Veja and IPT, and there are also examples of ancient dams in the said region (Institute de Pesquisas Technological do Estado de Sao Paulo [8]. In like manner, several dams have been constructed in Iran, and regarding the increasing idea of using underground dams in the rural developmental projects, some are also under construction [4].In association with groundwater flow and identifying the hydraulic behavior of underground dams, various studies have been conducted, such as: the conducted researches, on the effects of constructing underground dams on the aquifer fluctuations, the interference of fresh and seawater, and the land subsidence in Thailand's Phuket Island, by using MODFLOW mathematical model [2 and 6]. The underground water modeling and MODFLOW model on simulating the behavior of aquifers and their reactions toward the management method of feeding and exploiting have been diversely used in [5].

MATERIALS AND METHODS

Site description
The geographical location: Koohzar region, located in the southeast of Kor River, among the Latitude of 35, 20, 17" to 35, 30 degrees north, and the longitude of 54, 22, 30, to 54, 45, 08 degrees east of the Province of Semnan. This field has the total area of 1152.5 Hectares, and leads to Haj Aligholi desert [12].

Climate and hydrology

Table1: The summary of Water resources and Climate status of Koohzar Region

Average rain rate	200 mm
Penetration rate	17%
Annual sustenance of the resource	234600 m^3
Annual average temperature	22.2$^{\circ C}$
Annual evapotranspiration rate (average)	2000mm
Climate	Semi desert, cold and arid
Surface water flow	seasonal
The existing water resources	One Qanat (which can finance 1.5 L water per sec)

Table 2 Hydrological parameters of Koohzar waterway bed alluvium

Q of subsurface flow	0.6 liter per sec (average)
Hydraulic Gradian	0.038
Capacity coefficient	11%
Transitivity coefficient	10 m^2 per day
Alluvial material	Less gradated
The material of almost impervious bedrock	Volcanic (agglomerate)
Maximum alluvial thickness	8 m
Chanel width	150 m
Surface declivity	3%

Methods:
In this study, and to achieve identical goals, a simulation of the groundwater flow of the underground dam was done, by using a mathematical model. In this study, method of research includes conducting dam aquifer basic studies for the determination of some parameters like hydraulic conductivity values of dam reservoir, topography of reservoir and situation of bedrock depth, input and output situation of the plain with fulfilling field visits and field tests and

based on which, determination of area of aquifer and provision of conceptual model has been carried out. The simulation in this study was done, by using the MODFLOW and PMWIN code, and based on which, culture application development is presented.

Vegetation and current exploitation

The current exploiting from the lands of this region is as grassland. The small size of this region has caused in the failure of considerable surface water flow occurrences where its life with 35000 heads of cattle and 200 hectares of cultivating lands depend on exploiting subterranean water. Today, due to the shortage of water only 25 to 30 hectares of the region is under cultivation. Due to the limited water resources and rainfall in the region, the importance of land along the main drainage valleys and orchards of fruit and forage crops is very high. Wheat, Barley, Gropes and Pomegranates of traditional culture in the region. The vegetation in the region of the plant Sociology is among the shrubbey.destruction of vegetation, dominated rangeland pasture are low-value crop (forage terms).But in term of soil erosion are important.

Technical specification of Koohzar underground dam

The dam is located furthermost the watercourse and before the plain's entrance. It is eight meters high and 150 meters long. The reservoir's total alluvium volume is 56610 cubic meters, and the volume of stored water is 6230 cubic meters. The sealing wall is made of brick with cement and sand mortar, and its upper layers are sealed with Bitumen and Jute.

Water exploit facilities are designed in a way that the required water for the expected use can be provided, even in the conditions that the water level is at its lowest point. Given the bedrock located in the reservoir area limit faces frequent changes, the water exploiting well is contrived in an area where the water has the maximum depth, to face no interruption during water pumping. There is also a lower tipper on the dam's rim and close to the Thalweg (valley way). In regard with the dam's height, the water exploitation is done manually through a centrifugal pump.

RESULTS AND DISCUSSION

In order to achieve the expected goals, and after examining various models, the MODFLOW model and PMWIN software were chosen for modeling the underground dam area of Koohzar.

The mudflow model

MODFLOW consists of a single main program and several subroutines called (Module). In this model the amount of time decided for simulation, was divide into several pumping periods (cycles) and each period itself was divided into several time steps. Each time, the partial differential formula of water flow in the saturated porus media is calculated and solved, through the finite differences method. The matrix solution (n * n), in MODFLOW software is as repetition which is calculated for the result of the underground water level for each model networks in each time period (Rahimian M, 2007). Due to its high capability and having several subroutines that include various parameters of a system consisting underground waters, this is a nearly complete model from the numerical modeling aspect of a system flow, in saturated environment and alluvial formations.

processing mudflow for windows (PMWIN):

One of the complete software packages in hydraulic simulation of underground waters in the world which has Pre-processor and Post-processor three dimensional flow model of Modflow-96 and Modflow-97 with advance capabilities such as: simulation of wells effects, rivers, drains, boundaries associated with hydraulic loads, subsidence and solidification, Evapotranspiration and Alimentation. The steps of model making in the examining range are shown in figure 1.

Numerical method

The examining area conceptual model specifications

This particular model of the bottom and waterway sidewalls and the Dam's axis (pivot) belong with the model, which is without any water flow and the upper border belong with the model, which is the entrance of the water flow. The conceptual model used here is made of a single layer and of three dimensional net, comprised of ranks and columns. The results of the simulated model in the condition before and after the Dam construction and water exploit through well are explained below.

The water flow simulation before the construction of underground dam

The achieved results in this part show that water table stands parallel to the bedrock. Also the amount of input and output from the calculated range, either by using the model or analytically equals to 0.000004 cubic meters per second, per unit width. Figure two shows the simulated water table monthly before the construction of underground Dam.

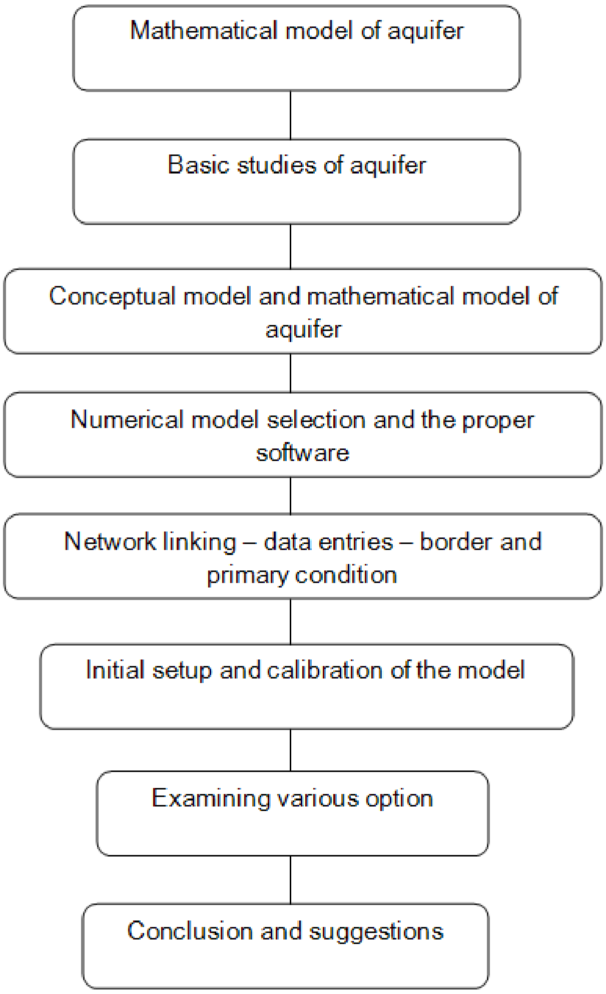

Figure1: the complete scheme of model making steps of underground waters through

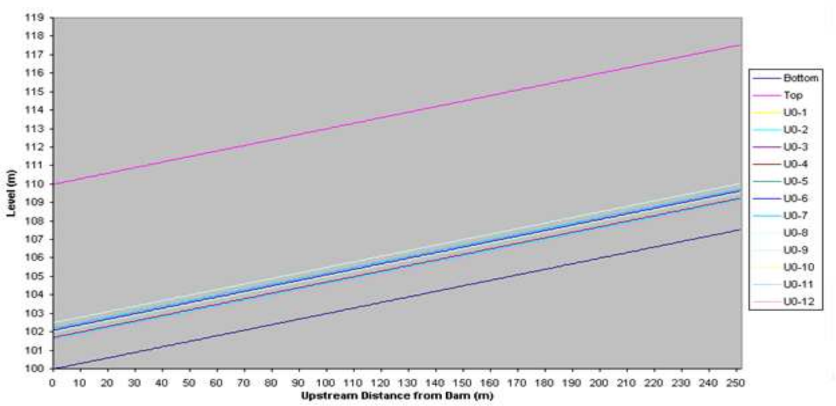

Fig 2 :Simulation Water table as monthly In unsteady condition (befor constraction of underground dam)

The water flow simulation after the construction of underground dam

The figure three shows the change in water table levels in the year after the construction of underground dam has been shown.

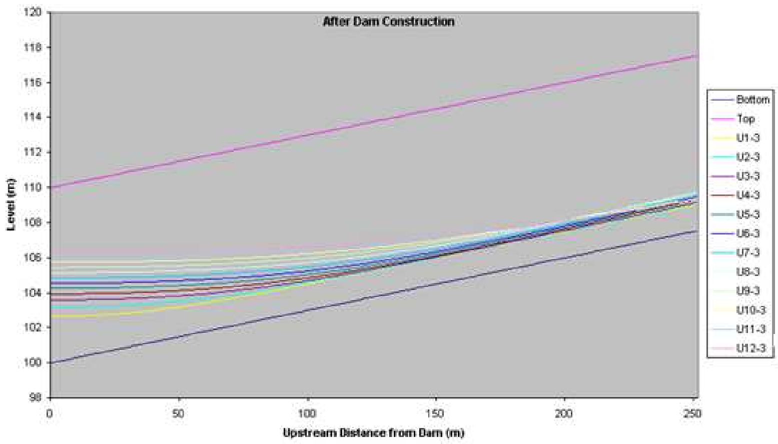

Fig 3: Changes in groundwater levels during the first year of the underground dam

The simulation of water withdrawal from reservoir through well

as mentioned above, to exploit water from the dam reservoir, a well was built near the dam rim, inside the reservoir itself, and conjoining the axis of the reservoir, and according to the reservoir's water capacity, the amount of exploitable water is measured each month, according to the amount of water that can be welled, by taking into account the amount of its dryness.

The simulation of the cortical water flow for the well pumping management for land Cultivation development

Regarding the climate of the area and because the harvest season is during spring and summer using the surface flows for cultivation is common in this area, the water pumping period in this simulation is limited only to the summer. The results of this simulation the figure four shows that four show that the maximum rate of water exploit from the Well is estimated as 30 cubic meters per day. It is necessary to note that by examining the maximum exploitable water for a five month period from the Dam, according to the simulation is estimated as 20 cubic meters per day.

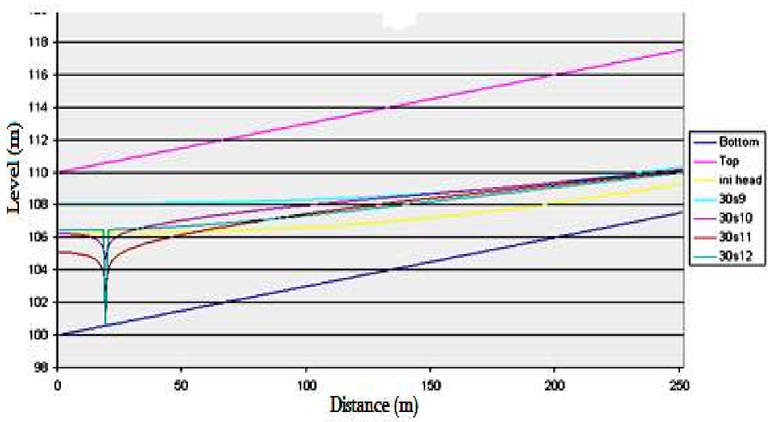

Fig 4: Maximum withdrawal rate during maximum consumption duration from the well is equal to 30 m^3 per day

The comparison of the options for different cultivations

According to the type of cultivation in the area, the rate of cultivating two kinds of grape and pomegranate were studied. Based on the daily water consumption of the mentioned crops and the maximum daily exploitable water from the Dam, the number of cultivable trees and maximum surface of extensible horticultural lands or vegetation can be calculated.

Due to the evapotranspiration rate of the designated type of plant and the plant co efficiency, available for each plant, the water needs for each plant was determined. This rate for grape, pomegranate, and non-productive types of trees is equal to 0.13, 0.10, and 0.025.

CONCLUSION

In this study, the simulation of hydraulic behavior for examining the efficiency and performance of an underground dam to provide water from the cortical sources in production centers located on the edge of the desert that faced the shortage of water and also the possibility of developing the area under cultivation, based on the maximum rate of exploitable water from the Dam's reservoir, by using the numerical model were examined and studied. by using the underground dams, one can easily create spaces for the storing and extracting subterranean water in the remote areas and those located on the edge of the desert, where they are usually out of reach, with respect to technical issues,

Mentioned above. Despite having difficulties and problems, related to its calibration on small scale alluvial, located behind underground dams, the numerical model of MODFLOW possesses ideal capability to manage and program the water exploit operations in

An underground dam. Determining the maximum rate of exploitable water from the dam, based on the conducted simulation, by using numerical model in a specific period, shows that it is indeed possible to cultivate crops, 0.54, 0.7 and 2.8 ha such as grape, pomegranate, and non-productive types of trees, resistant to drought, and developing the lands, which are under cultivation, despite the existence of water shortage in these areas.

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