International Journal of
Science and Engineering Investigations
vol. 5, issue 58, November 2016
ISSN: 2251-8843

Assessment of Effects of Drought on the Underground Water Resources

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Abstract- Drought is a normal, recurrent feature of climate. Though it has been assumed rare and random event, but it occurs in all climatic regions. In this study, data on monthly rainfall of 9 stations located in a province of Iran, in the period of 27 years were prepared and investigated. Because of the special situation and topographic characteristics of Iran, the climate is different. The average annual rainfall of about 224 to 275 mm is mentioned. After simulation and validation of models, allowable water exploitation and drop of water level in the aquifers was considered. In this research 3 stations were (D1, D3, D4) has been defined as separate unites for models. Analysis and Hydrographs of plains, show that one of the zones had less downward slope in comparison with others, because of the location, absorbed wells and collecting system which feed the plain and slightly less affected by drought. Steady exploitation of each station from 2 to 20 cubic million, shows the drop of 0.43 m of aquifer level (from 0.93 m to 0.5 m), which is considerable amount in comparison with current well arrangement (ten percent of water drop).

Keywords- *Groundwater, hydrography, water level, drought*

I. INTRODUCTION

The role of water resources management as an infrastructure of development for many countries is vital. Studies and estimations of economic planning commission of UN show that global warming damage the world economy about 30.4 million dollars till 2050(planning and Management organization of Iran). So, reserving, reclamation of water resources is very important. However, optimum exploitation of water resources needs recognition, preserve and/or reducing affected factors on the water loss. Affected factors on this vital resource divided on following groups:

- Natural factors as drought, typhoons and heavy rainfalls.
- Techtronic factors.
- Human factors comprise of forest destruction, wrong irrigation methods, changing land control, deforestation, destruction of lands, dam construction.

Since the definition of drought is always a troublesome obstacle for monitoring and analysis of drought, many researchers have analyzed the definition of drought. Drought is a normal, recurrent feature of climate. Though it has been assumed rare and random event, but it occurs in all climatic regions, but the period of occurrence is different in the regions, so that at the arid regions it happen many times but less in rainy regions. Drought is a temporary disorder and is different from arid regions with permanent low annual precipitation. The most common definition of drought is shortage of precipitation for a period, a season or more. This problem leads to water shortage for some activities, groups and/or a part of environment. Dracup et al. (1980) and Wihite and Glantz (1983) investigated more than 130 definitions and finally identified 6 general categories of drought consist of meteorological, climatology, atmospheric, agricultural, hydrological and water resources management. All definitions are presented and analyzed based on the principle that drought occur due to lack of moisture caused by the rainfall deficiency during a specified time period, are associated with the shortage of usable water resources, and depends the period in which deficiencies takes place.

Vogel (2000) has divided effects of drought on the rural regions of South Africa. These effects divided on seven parts comprise of agriculture, animal husbandry, water, occupation, price of foodstuff, pasturage and fuel. He describes the effect of drought on the water of rural parts as decreasing, loss and pollution of it and explains the consequences of that as human diseases, loss of animals, decreasing and loss of products and migration.

Vogel et al. (1998) described a list of direct and indirect effects of drought and their relations in the South African countries. They divided these effects to social, environmental and economic effects. According to their opinions economic effects of drought and the consequences comprised of slump, shortage of foodstuff and energy, loss of products that is used for food and income, decreasing the quality of bestial products, water shortage, loss of occupations, income and wealth, loss of tourists and recreation and pressure for taking financial resources. Haung et al. (2000) have investigated the effects of drought in China. They mentioned that drought affects urban life and industries, so that 30 percent of cities faced with water shortage. Therefore, industry products decrease 30 billion dollars and production of electricity by water resources decrease 13.7 million megawatt. Benson and clay (2000) during the reading and collecting opinions of other researchers examined the effects of drought in sub-Saharan Africa. The researchers also expressed countries economic structure and studied the effects of different economic sectors. These countries had a different infrastructure, but the rate of drought affection on them was severe. For example, after 1991 drought in Zimbabwe industry sector GDP decreased 3.9 percent and 6 percent of revenues of industrial exports decreased. This decrease was due to water rationing in industrial cities, reducing hydroelectric power production, agricultural production, demand for agricultural inputs and other consumer goods and increasing public debt as a result of finance to offset drought. Lundquist (1993) introduced the water as the most threatening vital source of life. He justifies this matter that it cannot be found any normal substitution for water in the field of protection of vital system and industrial production. Gwbeu (2002) investigated the management of urban water shortage in a case study of Bolivia during the period 1989 to 1993. The researcher believes that the issue of water shortage Bolivian is due to human causes and original. Limited and variable rainfall regime in this region is associated with drought, has made the lack of water as a chronic problem in this area and the problem exacerbated due to urban development and with growing demand for home, office and industry. The researcher suggested short, medium and long term strategies to solve the problem of water scarcity. Short-term strategies was adopted after drought in 1992 in Bolivia so that rationing based on daily water consumption in the 73000 cubic meter and adopt penalties for domestic and industrial consumers that excessive use. According to the results of this study, the most important and longest effect of rationing is economic and social vulnerability to water shortages in urban areas. Medium-term strategy consisted of seeking groundwater and long-term strategy includes wastewater recycling and water exploitation of new reserves. The researcher explained that by implementing the first method 20% of the water is returned, and 23% savings in water consumption and for the latter method introduced three new to supply water for the city. He estimated water project costs about 73.0 billion dollars and the cost to the final consumer 3.0 dollars per cubic meter of water, and stated that this amount is too expensive for low-income groups and subsidies on water are inevitable. In a study Iglesias and colleagues (2003) examined drought management in three areas of the country Spain. Researchers introduced the agricultural sector as the biggest consumer also the first victim of the lack of water supply in the region. They evaluated the economic consequences of hydrological drought on the irrigation sector with a turning dynamic mathematical model with assuming an incomplete transportability of capital and labor and rational expectations about future water availability over the period 1997-1991. In this study, storage and allocation of water, water shadow price, gross profit, net profit, the market value of the product, rental labor force and financial costs evaluated for the three areas of study during this period. Based on this study drought had different effects on farmers, workers and the entire community in the three study areas, among the three studied regions, the maximum devaluation of the rental labor force, market and the net profit was 60% during periods of drought. This paper investigate drought, among effective factors on the water resources, which affected many countries economy.

II. MATERIALS AND METHODS

Catchments under study are located in western Iran and the region has an area of about 26,416 square kilometers in the South West of the country. Due to the topography use of the surface waters of this region is very difficult and costly, and in some areas it is almost impossible. Therefore, underground water source (sedimentation tanks and reservoirs karst) is the only source of fresh water for the people of the region. In this study, data on monthly rainfall of 9 stations located in the area of the organization of water resources in a period of 27 years was prepared. Average annual rainfall varies from about 380 millimeters to about 880 millimeters in parts of the tropical to cold regions, and winter rainfall takes between 49 to 56 percent of the annual rainfall of the region. Basin area has a cold climate with annual precipitation of about 520 mm and 115 mm evaporation annually, according to this, groundwater resource has long been used as the main source of water. To identify the material, thickness of sediment layers, bedrock and their relationship with adjacent formations of plain, number of observation wells drilled over the past few years in the region and a range of sedimentology and soil samples have been analyzed. Average annual temperature of the basin is 16.7 ° C. climate of the region was evaluated by two methods Domarten and Emberger. In Domarten method which is based on average annual rainfall in millimeters and the average annual temperature in degrees Celsius climate of the region is very humid type.

$$\mathrm{I_A} = \frac{\mathrm{P}}{\mathrm{T+10}} = 44 \tag{1}$$

$$\mathrm{P} = 1175 \tag{2}$$

$$\mathrm{T} = 16/7 \tag{3}$$

P = The average annual rainfall in millimeters

T = The average annual temperature in ° C

Climate in Emberger method determined by three parameters including P (Average annual precipitation in millimeters), M (The average maximum daily temperature in degrees Celsius of the hottest months of the year) and m (the average minimum daily temperature in the coldest month ° C). Based on these three parameters Q factor is calculated as follows:

$$\mathrm{M} = 22/8 \tag{4}$$

$$\mathrm{m} = -8/3 \tag{5}$$

$$\mathrm{Q} = \frac{2000\mathrm{P}}{(\mathrm{M}+273/16)^2-(\mathrm{m}+273/16)^2} \tag{6}$$

$$\mathrm{Q} = \frac{2000\times1175}{(295/96)^2-(264/86)^2} = 134/7 \tag{7}$$

According to the value of Q and Emberger chart, river basin is a mountain climate. Fig.1 presents the project area located in the research area and river irrigation system of these units

Figure 1. Units of research areas

III. ENTERING DATA TO THE MODEL AND STUDY AREA NETWORKING:

At first, grid dimensions of this range were considered 1 x 1 km, then in areas where the river passes, because of the need for higher accuracy, each 1 km network divided to 4 parts, so local networks in the areas of crossing the river is 250 meters. The maximum number of columns and rows of grid lines are135 and 103 and the number of active cells in the range are 1302 (Fig 2.).

Figure 2. Meshing of model range

IV. BOUNDARY CONDITIONS

Defined boundaries of the groundwater simulation programs are similar in structure, but sometimes have different titles which user should be familiar with them already and then use them. Visual Modflow borders that exist in the model used here include (Fig 3.):

1. Constant head Boundary
2. Walls or obstacles for horizontal flow (Walls or Horizontal – Flow Barriers)
3. Head boundary condition variable in time (General Head Boundary)

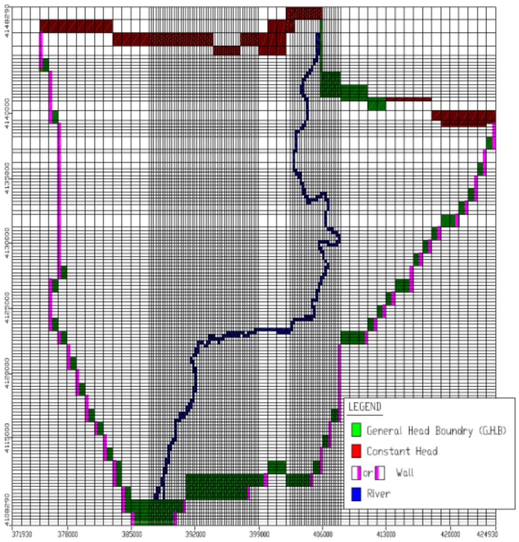

Figure 3. Study area boundaries

V. FLUCTUATIONS IN WATER LEVEL

In general fluctuations in the water level in the area was taken by 56 observation wells, the position of each observation wells in the study area is presented in Fig 4. For stable conditions the average water level in the water wells considered during the rainy season and for unstable conditions, water level values for each of the months of the year was given to the model.

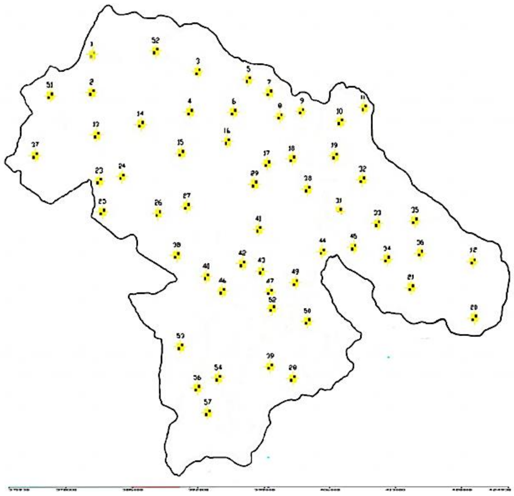

Figure 4. Distribution of observation wells

VI. THE GROUND FLOOR LEVEL OF THE AQUIFER AND AQUIFER THICKNESS

In the study area earth's surface elevation specified by topographic maps and elevation profile, but aquifer thickness is specified at 85 points and the thickness of aquifer in the study area varied from 80 to 260 meters. At first, the thickness of aquifer interpolated by using Geo-statiscal Analyst in Arc GIS with 85 points and by kriging method. The information can then be converted from Vector to the Raster mode, in other word, the thickness values can be obtained with any desired dimensions, in the range of model cells. Visual Modflow take surface and bed rock data and automatically calculate the thickness of aquifer and then draw the contour line with any desirable interval.

VII. HYDRODYNAMIC PARAMETERS AQUIFERS

Using exploratory wells drilled in the past studies, ground water transfer coefficient map has been prepared and the values of T (transmission coefficient) are available on-site exploration wells. However, information Visual Modflow simulation model requires is hydraulic conductivities values (Conductivity) for each of the cells of the range model.

Since:

$$K = {}^{T}\!/_{b} \qquad (8)$$

T (transfer coefficient) (M2/day)

K (Hydraulic conductivity) m/day

b (Thickness of aquifer) m

T parameter using existing data varies from about 100 to about 500 square meters per day and parameter values k varies from 2 to 26 meters per day in the region.

The reserve coefficient was considered initially by an average 5% and then in the calibration step value was correct.

VIII. AQUIFER RECHARGE

In the Visual Modflow total amount of recharge values that exist in every part of the study, can be entered to the model by recharge set. In this plain recharge aquifers include:

1. The infiltration of water from the river bed
2. The infiltration of sewage
3. The penetration of irrigation water
4. The Penetration of rainfall
5. Inflows from the basement

The amount of infiltrated water from the river bed which penetrated of the river is calculated automatically by River set. Groundwater studies showed that the total amount of rainfall infiltrated water in the aquifer with respect to vegetation, topography, surface, ground material, high permeability of the ground and eventually the groundwater level in most plain areas, is about 8 percent.

IX. RESULTS AND DISCUSSIONS

Water Resources Management Organization statistics show that nearly 85 percent of the country is the arid and semi-arid regions and drought have occurred frequently over the past three decades in the country, thus, it is not unexpected drought in the coming years. At the first part of the research, climate is assessed by use of indicators of climate average annual rainfall, and then at next step using the software Visual Modflow, drought in this area will be examined. Visual Modflow by default considers the entire area as the primary area (Zone) and if user wants can add other areas. In this study, through this series, 3 Development Unit D4, D3, D1 was defined as a separate region for the model. 2010 to 2013 is obtained simulation model year. After running the program with entry of hydrodynamic coefficients with data table (S, T), feeding and discharging parameters (R), define initial and boundary conditions, the water table level (h) is calculated cell to cell for different times (Fig 5).

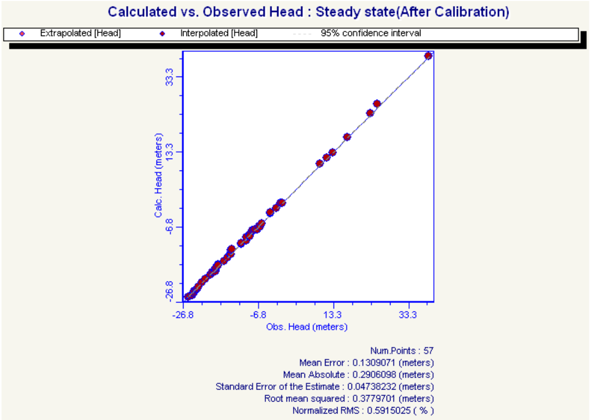

Figure 5. The water level calculated relative to the observed stable condition after calibration

Distribution wells with existing conditions is indicative of a poor distribution, so that in some areas there is the density of the wells and it causes increasing of water withdrawal over 10 m and extreme drops of water level, during drought and reduced surface water resources. In Development Unit D1 when the withdrawal increases from 2 to 20 million cubic meters, the maximum water level in the aquifer drops from 0.8 to 9.7 m. By steady exploitation of water across each development unit, drops of water level in the aquifer decreased extremely, so that, in the unit D1 when the exploitation increase from 2 to 20 million cubic meters, the maximum water level drawdown in the aquifer increase from 0.5 to 0.93 m, that drop amount is one-tenth in comparison with current makeup of the wells. In this case, the amount of withdrawals from the aquifer can be significantly increased, because the need to withdraw from the aquifer is high in drought conditions. The amounts of available water in the project area D1, D3 and D4 in aqueous medium in the irrigation season are 101.1, 60.51 and 54.21 million cubic meters, respectively. However, the amount of water in the project area in the dry season in D1, D3, and D4 was reached to 47.7, 28.9 and 26.37 million cubic meters, respectively. In other words, available water in the dry year in comparison with wet year, have been cut to less than half of its value. Finally, the lack of water in the project area D1, D3, D4 has increased of 26.1, 18.2 and 15.5 million cubic meters per year to 76.7, 49.2 and 42.5 million cubic meters per year in dry year. By analyzing these numbers it is clear that if it is needed to supply water from groundwater in the drought time, substantial withdrawals from the groundwater should be done to be effective for water shortage. However, the current distribution of wells and drops of water level in the aquifer, it is not possible to withdrawal large amount of water and distribution and withdrawal should change. To obtain the allocation of water from surface and underground water resources to meet the needs in different years and months, the optimization model was used. In this model, the results of the simulation model, the relationship between withdrawals from aquifers and drop of water levels in the aquifer was used. At first, optimization model was developed annually with regards to the steady withdrawal of water from aquifer, in which according to that at the drought times, without considering the withdrawal water, the total amount of water shortage is about 62 percent of total requirement water. However, considering the steady withdrawal, this shortage reduced to 8 percent, this means that by uniform withdrawal of groundwater in the project area d4, d3 and d1, at the drought time, 92 percent of total water requirement is supplied. The optimization model was also used for a monthly condition that the optimization model was used in two cases for the monthly mode. In the first case the amount of surface water resources in the project area and different known months was considered, this means that in every project unit and every month the amount of required water was determined. In the wet year unlike the dry year, surface water supply the most requirement. By exploitation water from aquifer, all the required water is supplied and the maximum loss in the aquifer is 1.3 m. However, in the dry years that there has been a drop in the aquifer reaches up to 2 meters. In the second case, the total surface water available for all units was entered for each month and for each unit in all the months of the model, but the distribution of these amounts among different units and months was determined by the model. In this case, the goal is to maximize withdrawals from groundwater and surface water resources, and considering that the priority is by surface water withdrawal, for the amount of withdrawal from surface water resources in the objective function, coefficient 2 was used. In other words, more weight was assigned to them. So once again the optimization model was established by adding more constraints and putting uncertain amounts of surface water for each unit and each month. In this case, compared to the previous mode that ground water resources was considered known, the drop has not changed in the aquifer water in the project area in over a year, because, total water taken from the aquifer in the different project area in this mode has not changed over the years and just only its distribution has changed per unit over the years. If allocation plan of water from surface water sources can change to these values, compared to the previous mode of ground water resources in different months and construction units, this program is considered to be more efficient.

X. CONCLUSION

In this study, data on monthly rainfall of 9 stations located in a province of Iran, in the period of 27 years were prepared and investigated. Water Resources Management Organization statistics show that nearly 85 percent of the country is the arid and semi-arid regions and drought have occurred frequently over the past three decades in the country, thus, it is not unexpected drought in the coming years. In this study, climate is assessed by use of indicators of climate average annual rainfall, and then at next step using the software Visual Modflow, drought in this area examined. Results of modeling show that by steady exploitation of water across each development unit, drops of water level in the aquifer decreased extremely, so that, in the unit D1 when the exploitation increase from 2 to 20 million cubic meters, the maximum water level drawdown in the aquifer increase from 0.5 to 0.93 m, that drop amount is one-tenth in comparison with current makeup of the wells. The optimization model was established by adding more constraints and putting uncertain amounts of surface water for each unit and each month. In this case, compared to the previous mode that ground water resources was considered known, the drop has not changed in the aquifer water in the project area in over a year, because, total water taken from the aquifer in the different project area in this mode has not changed over the years and just only its distribution has changed per unit over the years. If allocation plan of water from surface water sources can change to these values, compared to the previous mode of ground water resources in different months and construction units, this program is considered to be more efficient.

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