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# Spatial Variability Zonation of Groundwater-table by Use Geo-statistical Methods in Central Region of Hamadan province

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**ABSTRACT**

*Today's population explosion, industrial improve and agricultural development has increased the extraction of groundwater resources, As groundwater resources are the most important factors for development of arid and semiarid areas. In this study the geo-statistics methods are used to examine the spatial and timing variability of groundwater table of Central region of Hamadan Province in Iran, So the ground water statistical data in this region were accumulated and a data bank was prepared, Then the quality and the accuracy of data were controlled, Next the different interpolation techniques including Kriging, Inverse Distance Weight (IDW) to the power of 1 to 5, and Radial Basis Function method (Thin Plate Radial Function, Inverse Multi Quadratic and Multi Quadratic) and Cokriging method were used; After choosing the best interpolation methods using GSD and RMSE the spatial zonation map of groundwater table were drawn by Arc GIS. The analysis of geostatistical results appeared that the Spherical model was the best variogram specified to groundwater data in 1989, Circular model was the best in 1993 and 1999, and pent-spherical model was the best in 2006. Our findings got from investigation of interpolation methods by Cross validation showed that in all years of investigation, Cokriging method has had the less amount error in estimation and is the most suitable method. According these results the variable table of groundwater during the years of our research showed that the water table in this region has decreased noticeably and the use of these sources should be limited.*

**Keywords:** Spatial and timing variability, Groundwater table level, Land Degradation, Geostatistical interpolation, Hamadan, Iran

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## INTRODUCTION

About one third of the world population are dependent on ground water and more than 70% of groundwater resources are used for agriculture; in recent decades harvesting from above-mentioned resources has increased by growing in population and development of agriculture; In this situation, ground-waters are the most important resources for exploiting and developing in arid and semiarid areas. Central region of Hamadan Province belongs to semiarid according to De matron Climatic classification and it belongs to cold semiarid according to Emberger Climatic classification system [2].

About 88% of water consumed for industrial, agriculture and drinking consumptions in this area has been provided from ground-water resources and about 12% has been provided by superficial water thus, the investigation of ground-water changes in this area and permanent examination of aquifer have special importance [2].

Various studies have been done in order to investigate underground water resources and the results have shown this reality that the best method for investigating the quantity condition of aquifer is simulation by using mathematical models with computer that its simulation is very difficult and time-consuming [8].

With regard the importance of groundwater resources, several researches have done to find a replacement method with aquifer simulation method that one of the most important ones is compartment parameters of aquifer by use the geo-statistical methods. In this direction Theodosia and Latinopoulos (2006), also, Ahmadi and Sedghamiz (2007) Showed that many aquifer parameters contain structure of spatial variability, and with investigation of ground-water fluctuation, they classify aquifer by using geo-statistical methods[1,9].

The studies done by Vijay and Remadevi (2006) showed that in estimation of groundwater table, Kriging method is more accurate than Inverse distance weight method [10].

Dick and Gerald (2007) consummated the research with title, *Optimization of the models of sampling of environmental variables using public Kriging*, in Netherland. They calculated by investigating the highest average of ground-water table, usual Kriging Variance for 25 samples is 19%, and for 50 samples is 7%, and for 100 samples is 3% less than usual Kriging method [5].

Safari (2001) achieved the research with title, *Investigation of the net of the best measurement of groundwater table of Cham-chamal plain by using geo-statistic methods.* He eliminated some points of the net, which had been estimable using adjacent points and in turn selected the points with the highest errors in estimation in order be added to the net, and then he investigated the result of decrease in the error of net estimation by increasing any of these points. The acquired results indicate that provided data is successful application and this model is more real [12].

Mashal and associates (2006) introduced the research with title, *Evaluation of pizometers wells of groundwater table using geo-statistic methods in Arak plain,* numerical data of water table measured in 46 points in 3 different period (wet, medium and dry). They concluded that Gus diagram models as the best variogram for these data; by comparing of Kriging, Cokriging and Inverse Distance method, 3 that Cokriging method has less error in comparison which others[14].

Recent study is going to do spatial and timing variability's ground waters using geo-statistic techniques with investigating different interpolation methods; this study is going to introduce the best interpolation method for conducting and classification the underground water variability in Central region of Hamadan Province via geographic information system (ARC-GIS).

## MATERIALS AND METHODS

### 1. The Position of studied region and characteristics

The domain, which was studied, contains some parts of central region in Hamadan province with the area of 171699 hectare that are located between North width of 35°21′ to 35°52′ and eastern length of 48°09′ to 48°30′ with the average height of about 1700 meters from sea level. In Fig 1, the map of the geographic position of the studied area has recognized [2].

The domain of studied plains according to universal conditions of geology of Iran in the northern domain of Sirjan-Sanandaj zone in universal trend of Northwest-Southeast in northern part the main steer of Zagros is located. It is more or less similar to central Iran geography conditions with regard to Lithology and structural features (the lack of volcanic formation of the third periods of geology) and the conditions of discontinuity.

According to geology, the studied region is generally consisted of Jurassic exposure frocks to the third periods (Tertiary) along with related to the fourth periods (Quaternary) which include the borders of studied plains in northern front of Alvand.

### 2. Selection of common statistic timing base

The closest meteorological synoptic station for the studding region is Nojeh station, the rainfall and temperature statistic from 1986 to 2009 has been selected and the statistics of evaporation and transpiration from meteorological stations of Zehtaran, Amrabad and Qahavand been selected. Census data then investigated and their periodic averages were calculated.

According to variance and standard deviation which were estimated and the comparison inside groups of these parameters and also by long-termed average, at last the period which didn't have meaningful difference than each other and total average were selected by SPSS statistic software; these periods consist of water years 1992-1993(contemporary with constitution of Mofateh thermal power plant) and 1998-1999 (contemporary with constitution of Vian industrial collection) and 2005-2006 (After expansion of Mofateh thermal power plant and Vian industrial collection). Water year of 1988-89, which is the first year of studying plain (Before than any industrial expansion) selected as an evidence of the region [2].

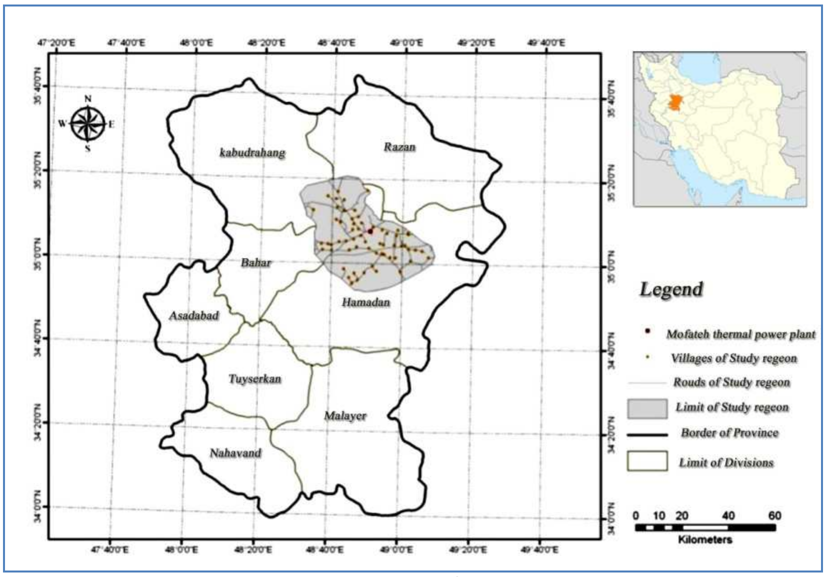



**Fig 1: The position map of study region [2]**

**3. Analysis of Pizometer wells data**

To do this research out of 47 pizometer wells located in the region that its data that gathered by the Ministry of Power an Iran government, in Figure 2 the position map of these wells accompanied by communicative ways and villages has presented.

After collecting numbers and data and selecting distinct time base, the available lenses are investigated in case of quality, correctness and being homogenous of statistics by means of *SPSS* software; in order to investigate test of being homogeneous statistically the method of *Run Test* is used. Then normalization test of data done based on skewness and eventually statistic faults rebuilt by using coordinative method of a variable.

In order to generalize point data to a region, there are different methods; in a general classification, it can divide into geo-statistics methods and classic methods. In this study used the classic methods including inverse distance weighting and radial basis function, else the geo-statistic techniques consisting Kriging and Cokriging.

It is worth to mention that classic methods have existed before the geo-statistic methods constructed, in fact they are ancient and don't belong to geo-statistics methods; Thus variogram drawing isn't needed for these methods.

***3.1. The method of inverse distance weighting***

This method is based on this hypothesis that the effect of the event decreases by increase of distance So nearby samples should have more share than those that are located in farther location in order to estimate the unknown points

In this way, the more the distances of unknown point decrease, the more the value of weighting of those points increases and the points that its values are known, they will be estimated using nearby points of a definite radius that its equation is as follows[4]:

$$Z^{*}=\frac{\sum_{i=o}^{n}\left[{Zi}/{(hij+s)^{p}}\right]}{\sum_{i=o}^{n}\left[{1}/{(hij+s)^{p}}\right]}$$

In this equation $Z^*$ is the amount of estimation in the regarded point, $Z_i$ is the observed amount in a point for the distance of $h$ from the regarded point, $h_{ij}$ is the distance between the observed point from the estimated point, $s$ the factor of equivalence, and $p$ is the weight of point [4].

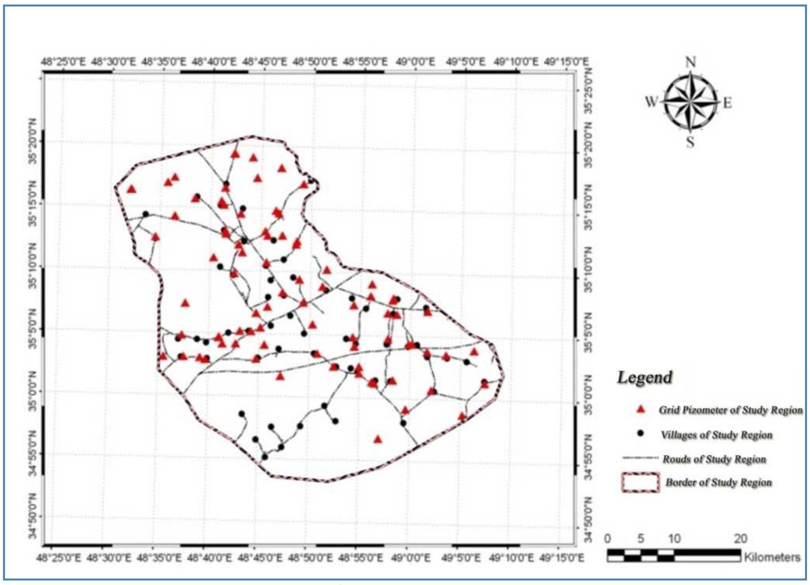



**Fig 2: The position of grid pizometere in study region [2]**

***3.2. Kriging method***

This method is based on weight mobile average which determines the extent of estimation error in each point addition to estimated amounts [7]. Using the exclusive feature of this method, the parts which contain many errors and need more data to decrease can be distinguished [5].

Not only weight Kriging method depends on the distance among observes and predicted point; but also it depends on spatial structure of point, too. For this reason, Kriging belong; to interpolation geo-statistic model, this method has different algorithm that its total equation is as follows [5]:

$$\hat{Z}(S_o) = \sum_{i=1}^{N} \lambda i Z(S_i)$$

In this equation $Z(S_i)$ is measured amount in the position of $i_{th}$ and $\lambda_i$ is the weight of measured amount in the position of $i_{th}$, Also $s_o$ is the predicted position and $N$ is the number of measured points or known ones. In this method, first suitable variogram has given to spatial structure of data based on the least amount of RMSE and then interpolation be done [5].

***3.3. Cokriging method***

In some cases, Variable may not be sampled enough; Exert estimation can't be done based them; in such cases, estimation can be revised by help of second variables using meted coordination between main and secondary variables; Of course, because there are some problems in making models of mutual variogram of variables, the Cokinging method hasn't enough validity in application.

Cokriging do by point and block method like Kriging; In fact, says that in classic there are statistic multi-variable methods; in geo-statistic methods, the coordination among different variables can be estimate like Cokriging method; of course, this method can be use on the condition that the coordination between two variables is more than 60% [11].

***3.4. Radial Bases Function method***

One of the methods of interpolation is the method in which the level of estimation passes through observed amounts; one of the features of this method, which is a state of the model of artificial nerve net, is that there are the amounts that are more than observable majority and or less than observable minority in estimation level.

In inverse distance method, the estimation level passes through observable amounts, too but this method does not estimate the amounts, which are more than majority and less than the minority of observable data [13].

The above-mentioned method does two interpolation of information based on five different functions the main core of these functions is the sum of the amounts of ($h^2$+$R^2$). The amounts of $R$ & $h$ related to the distance from point to loop according to smoothing factor and Anisotropically Rescaled factor [3].

In this study, radial functions were be used that are consisted of inverse multiquadric, thin plate radial function and multiquadric functions.

**4. Examination of suitable variogram method for spatial structure of data**

After empirical analysis of data, this action were done using SPSS software for those groups of data that needed normalization; in this stage, examination of variogram suitable model for structure of data was done in regard with the amounts of RMSE.

**5. The determination of the most suitable method of interpolation**

In order to evaluate and investigate the methods of spatial interpolation the technique of cross validation be used. This technique is as follows that, each time when an observable point has temporarily omitted and the calculation of estimated amount done for that point through nearby points: at the wad of this operation, a table with two columns created which consist of real and estimated points.

Having these two amounts the Root mean square and General Standard Deviation are determined in each method and the most suitable method can be selected; the related, relations are as follows [15]:

$$R.M.S.E = \sqrt{\frac{1}{N}\sum_{K=1}^{N} Z(x_i) - Z^*(x_i))^2} \qquad GSD = \frac{RMSE}{\bar{Z}(x_i)}$$

In above equation $z^*(x_i)$ is the estimated amount of variable $z(x_i)$ is the measured amount of the variable (observative amount) and $\bar{z}(x_i)$ is the average of observative amounts, *N* the number of observation. The more the amount of these two parameters is nearer to zero, the more accurate is the above- mentioned model [15].

After analyzing data empirically and according to less *R.M.S.E,* the measure to create of variogram done suitable for the spatial structure of data related to groundwater table and eventually according to goodness-of-fit test results of interpolation methods, the map of zonation of groundwater level of studying area in Arc-GIS9.3 software provided and analyzed.

**6. Providing a map for groundwater table**

The results due to the subtraction of the groundwater table height from the definite height of marked point used to provide the spatial zonation maps of groundwater table during the statistic period.

## RESULTS AND DISCUSSION

As mentioned before, following empirical analysis of data using SPSS software and according to less amounts of root mean square error (RMSE), suitable variogram model for the conformation of groundwater table data done those characteristics of suitable variogram of water table level for Embedded Parameters showed in Table 1.

In this study the aid variable of (H) is used which is definite height of signal point that shows the correlation over 0.8 with investigating variable.

Results from comparison of a mounts of root mean square error (RMSE) and general standard deviation (GSD) related to each of interpolation methods related to parameter of groundwater table indicates this point that the method of ordinary Cokriging has the highest accuracy than other methods during all studying year's.

**Table 1: Characteristics of suitable variogram of water table level for Embedded Parameters**

| Statistic period | Models | Kind of Variogram | Correlation Factor |
|---|---|---|---|
| **1989-1990** | Spherical | Semi variogram | 0.97** |
| **1992-1993** | Circular | Semi variogram | 0.97** |
| **1998-1999** | Circular | Semi variogram | 0.96** |
| **2005-2006** | Spherical-Penta | Semi variogram | 0.95** |

** *Limits of confidence: 99%*

The evaluation results of geo-statistic methods for estimating groundwater table are presented in table 2, according to the comparison of root mean square (RMSE) and general standard deviation (GSD) and mean estimate (MS) which been acquired by different interpolation methods. In order to provide the maps for spatial zonation of groundwater table, the results from the subtraction of the height groundwater level from the definite height of signal point used during the statistic period that the results have presented in table 3 and figs 3 - 7.

**Table 2: Statistical computed parameters of water table level for various interpolation methods**

| Statistical period | Mean of Observation Data | *Inverse Distance Weighting Method* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | IDW With 1 Power | | | IDW With 2 Power | | | IDW With 3 Power | | |
| | | RMSE | GSD | MS | RMSE | GSD | MS | RMSE | GSD | MS |
| 1989 | 1696.65 | 20.35 | 0.012 | 1695.31 | 16.91 | 0.01 | 1696.50 | 16.91 | 0.009 | 1696.64 |
| 1992 | 1685.55 | 26.19 | 0.015 | 1685.00 | 24.23 | 0.014 | 1686.24 | 24.15 | 0.014 | 1686.79 |
| 1999 | 1679.74 | 27.38 | 0.016 | 1677.70 | 24.90 | 0.015 | 1678.90 | 24.94 | 0.015 | 1679.95 |
| 2006 | 1673.88 | 34.92 | 0.020 | 1672.38 | 32.36 | 0.019 | 1674.08 | 31.59 | 0.019 | 1675.00 |

| Statistical period | Mean of Observation Data | *Inverse Distance Weighting Method* | | | | | | *Thin Plate Radial Function* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *IDW With 4 Power* | | | *IDW With 5 Power* | | | | *TPR Method* | |
| | | RMSE | RMSE | RMSE | RMSE | GSD | MS | RMSE | GSD | MS |
| 1989 | 1696.65 | 15.54 | 0.009 | 1696.50 | 15.49 | 0.009 | 1696.37 | 12.55 | 0.007 | 1696.48 |
| 1992 | 1685.55 | 24.51 | 0.014 | 1686.90 | 24.76 | 0.015 | 1686.87 | 26.01 | 0.015 | 1686.57 |
| 1999 | 1679.74 | 25.53 | 0.015 | 1679.55 | 25.93 | 0.015 | 1680.21 | 24.80 | 0.015 | 1679.46 |
| 2006 | 1673.88 | 31.52 | 0.019 | 1675.33 | 31.65 | 0.019 | 1675.42 | 34.07 | 0.020 | 1674.52 |

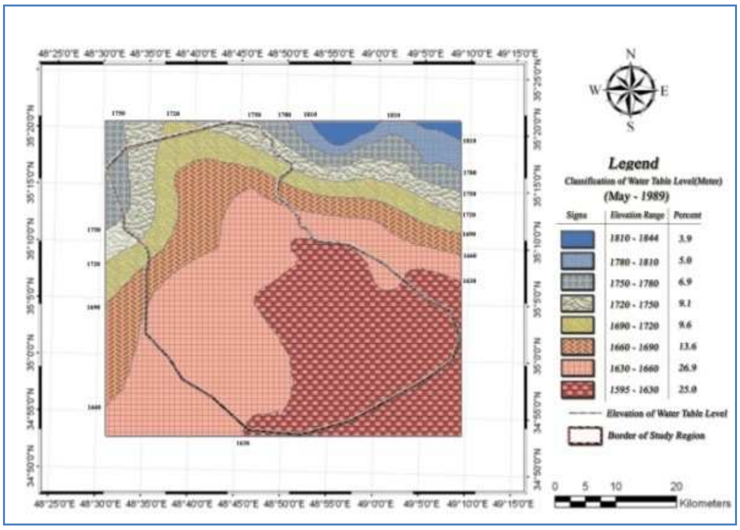
| Statistical period | Mean of Observation Data | *Multiquadric Functions* | | | *Inverse Multiquadric Functions* | | | *Simple Kriging* | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *MF Method* | | | *IMF Method* | | | *SKR Method* | | |
| | | RMSE | GSD | MS | RMSE | GSD | MS | RMSE | GSD | MS |
| 1989 | 1696.65 | 13.38 | 0.008 | 1696.77 | 13.38 | 0.008 | 1696.77 | 13.38 | 0.008 | 1696.77 |
| 1992 | 1685.55 | 22.97 | 0.014 | 1686.22 | 22.97 | 0.014 | 1686.22 | 22.97 | 0.014 | 1686.22 |
| 1999 | 1679.74 | 22.72 | 0.013 | 1678.98 | 22.72 | 0.013 | 1678.98 | 22.72 | 0.013 | 1678.98 |
| 2006 | 1673.88 | 31.26 | 0.019 | 1673.21 | 31.26 | 0.019 | 1673.21 | 31.26 | 0.019 | 1673.21 |

| Statistical period | Mean of Observation Data | *Normal Kriging* | | | *Cokriging* | | | |
|---|---|---|---|---|---|---|---|---|
| | | *NKR Method* | | | *CKR Method* | | | |
| | | RMSE | GSD | RMSE | GSD | RMSE | GSD | |
| 1989 | 1696.65 | 12.17 | 0.007 | 1696.50 | 8.19 | 0.005 | 1696.67 | |
| 1992 | 1685.55 | 23.18 | 0.014 | 1687.34 | 9.55 | 0.006 | 1686.80 | |
| 1999 | 1679.74 | 21.91 | 0.013 | 1679.71 | 11.88 | 0.007 | 1678.95 | |
| 2006 | 1673.88 | 31.04 | 0.018 | 1674.03 | 11.12 | 0.007 | 1673.92 | |

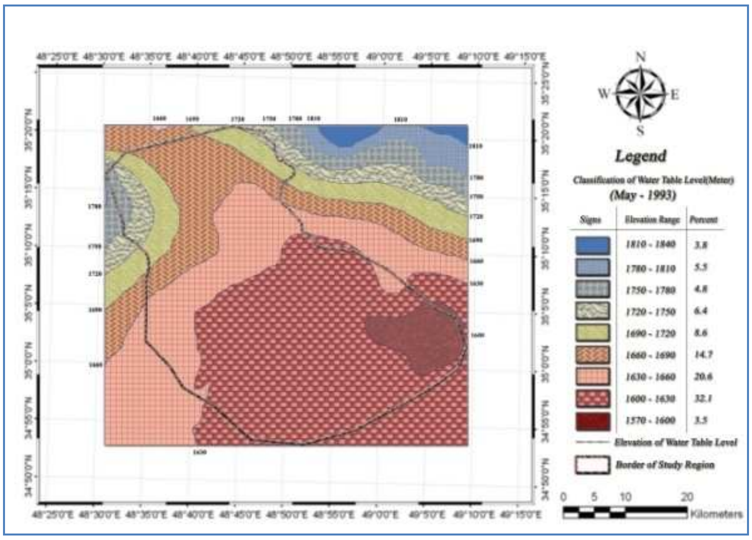
**Table 3: Survey classification of depth water table level during of statistic period**

| ranking | Water Table Rang | *Surface Area (vertical image above ground)* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | (May 1989) | | (May 1993) | | (May 1999) | | (May 2006) | |
| | | Hectare | Percent | Hectare | Percent | Hectare | Percent | Hectare | Percent |
| 1 | 1540-1570 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 19300.3 | 5.2 |
| 2 | 1570-1600 | 2598.1 | 0.7 | 12990.6 | 3.5 | 48621.9 | 13.1 | 54560.5 | 14.7 |
| 3 | 1600-1630 | 92790.0 | 25.0 | 119142.4 | 32.1 | 103553.6 | 27.9 | 70149.2 | 18.9 |
| 4 | 1630-1660 | 99842.0 | 26.9 | 76458.9 | 20.6 | 58272.1 | 15.7 | 83511.0 | 22.5 |
| 5 | 1660-1690 | 50477.8 | 13.6 | 54560.5 | 14.7 | 51220.1 | 13.8 | 43796.9 | 11.8 |
| 6 | 1690-1720 | 35631.4 | 9.6 | 31919.8 | 8.6 | 33033.2 | 8.9 | 25238.9 | 6.7 |
| 7 | 1720-1750 | 33775.6 | 9.1 | 23754.2 | 6.4 | 35981.2 | 7.0 | 24125.4 | 6.5 |
| 8 | 1750-1780 | 25610.0 | 6.9 | 17815.7 | 4.8 | 23383.1 | 6.3 | 23383.1 | 6.3 |
| 9 | 1780-1810 | 18588.0 | 5.0 | 20413.8 | 5.5 | 18558.0 | 5.0 | 17073.4 | 4.6 |
| 10 | 1810-1840 | 11877.1 | 3.2 | 14104.0 | 3.8 | 8536.7 | 2.3 | 10021.3 | 2.7 |

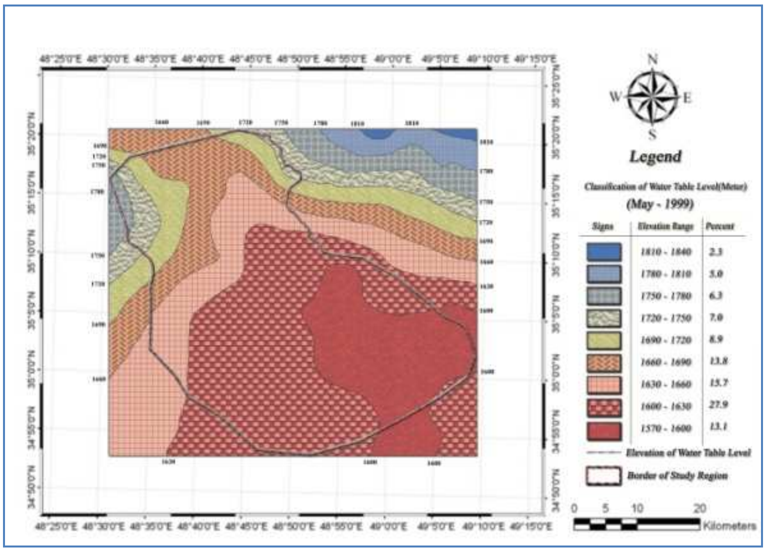
**Figs. 3: The interpolation map of water table level classified in reference Period**



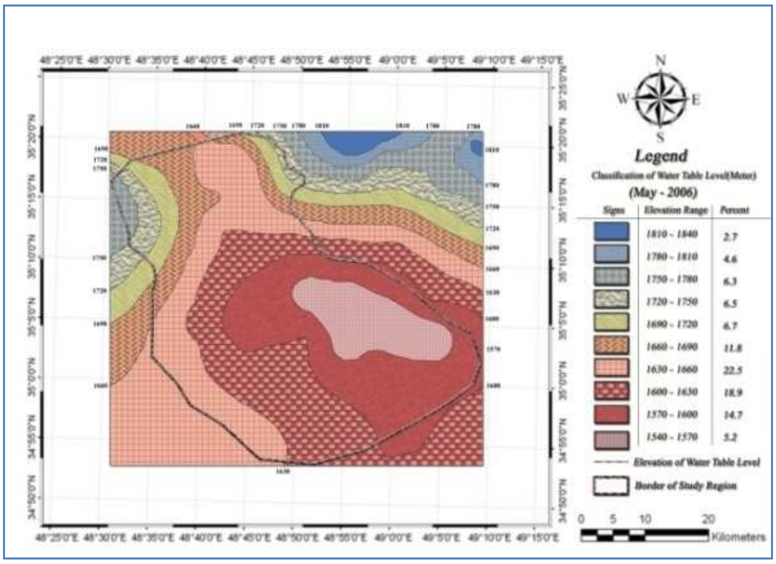

**Figs. 4: The interpolation map of water table level classified in the First of Period**




**Figs. 5: The interpolation map of water table level classified in Middle of Period**



**Figs. 6: The interpolation map of water table level classified in end of Period**




## CONCLUSION

The analysis of geo-statistic of groundwater table shows that the most suitable variogram specialized to data structure in 1989 is the spherical model; on years, 1992 and 1999 is the model of circular and in 2006 is the model of Pent spherical.

The analysis of the methods of interpolation of parameter of groundwater level with the help of Cross-validation method also showed that in all studying years, the Cokiging method has the least error in comparison with other interpolation methods and it is the most suitable, method.

It is worthy to mention that in Cokriging method, the variable H has used as the aid variable; in this way, the difference in observable data average and estimated data in Cokriging method is less than other methods and this result is in accordance with the results from Mashal and associates studies 2007, and Safari findings 2002.

The investigation of the maps of spatial zonation of groundwater table shows that the direction of groundwater current in all parts is toward the center of plain and at last empties from southeast part. The most recharge of aquifer as a result of the expansion of Cretaceous limestone and Oligo-Miocene Formation in north of the region and in contrast in western and southwest part induced recharge of alluvium is two slight because of the presence of impenetrable of Schist and marn stones.
The comparison of the contour maps of groundwater during the statistic period (1989-2006) shows the process of decrease the level of groundwater in aquifer, so that the lowest scope of groundwater table at the beginning of period 1989 was 1595m that at the end of period 2006 achieved to 1544m.

Studies have shown that some parts of plain in which the level of water table has been decreased during the studying period has been expanded from eastern areas towards central regions of the plain and at the end of studying period 2006, in central parts of plain, the lowest level of groundwater table has been created.

The contour maps of groundwater table show also this reality that at the beginning of the period 1989, the direction of the movement of groundwater has been from different parts of the region toward southeast of the plain and the total gradient of groundwater also is shaper from North and northeast than other direction And the least groundwater tables is 1595m; Among the period 1992, the direction of water and gradient of groundwater has been preserved than 1989 and they don't have conspicuous changes; but the domain of the least groundwater has been decreased and has been 1590m. The domain affected by lower water table expanded but this development is sensible towards northwest. The procedure in 1993 occurred similarly in 1999; in addition the least amount of groundwater table contour has moved to interior area of the plain.

Finally, at the end of the examined period 2006, the least amount of groundwater table contour has decreased to 1544m and has concentrated in the middle part of the plain. This is due to incorrect extraction of groundwater table in the interior part of the plane especially after 1993.

Many industrial units are located in this area like Mofateh thermal power plant in North width of $35°07'$ and eastern length of $48°50'$ and Vian industrial collection North width of $35°06'$ and eastern length of $48°48'$. There are many deep industrial wells and many un-allowed wells used for farming [2].

As a whole, we result that misuse managing and not permanent industrial and agricultural improvement have the most effect on this condition. So the main way to stand out against the present procedure of water decrease in this area and the same areas in which there are sensitive ecologic conditions, is to have correct industrial and agricultural management and adaption which these conditions to protect the natural sources in line with permanent improvement.

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