GIS in Water Resources Term Paper

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Identifying spatial extent of critical conditions in Salt lake valley

Introduction

Groundwater and surface water are the two resources of water to satisfy the agricultural, industrial, and municipal demands. Groundwater resources have a special importance for regions that surface resources are not sufficient. The regions with appropriate surface water resources also might face shortage in available water during some warm months. So, using groundwater would be inevitable in many areas in the world.

On the other hand, excessive withdrawal from groundwater resources would have unpleasant effects such as lowering the water table, reduction of water in streams and lakes, deterioration of water quality, and land subsidence.

Therefore, it is important to investigate the groundwater conditions to assure that those resources would be reliable and safe for sustained and long-term usage.

In this project, groundwater conditions in Salt lake watershed with HUC8=16020204 has been studied using ArcGIS. This watershed covers nearly whole of Salt Lake County in Utah State. Fig 1 shows the study area. Some parts of this watershed especially in the east are mountainous areas which are not used in our study.

Objectives

The objectives of this study have been defined as follow:

1- Obtaining interpolated surface of groundwater elevation and depth of unsaturated zone

2- Specifying the critical areas

3- Specifying the regions possibly affected by artificial recharge system

4- Specifying the regions with high pumping cost

We have discussed each of these objectives in results and discussion section

Needed data

1- Groundwater observation wells data

The key data for investigating groundwater conditions in any study area is groundwater elevation data that can be achieved in observation wells. For acquiring those data in our study area, United States Geological Survey (USGS) is the best resource and we use USGS website to obtain observation wells data. Due to the fact that there are not sufficient monthly data for observation wells in Salt lake valley, we investigated groundwater conditions in our study yearly between years 2001 and 2011.

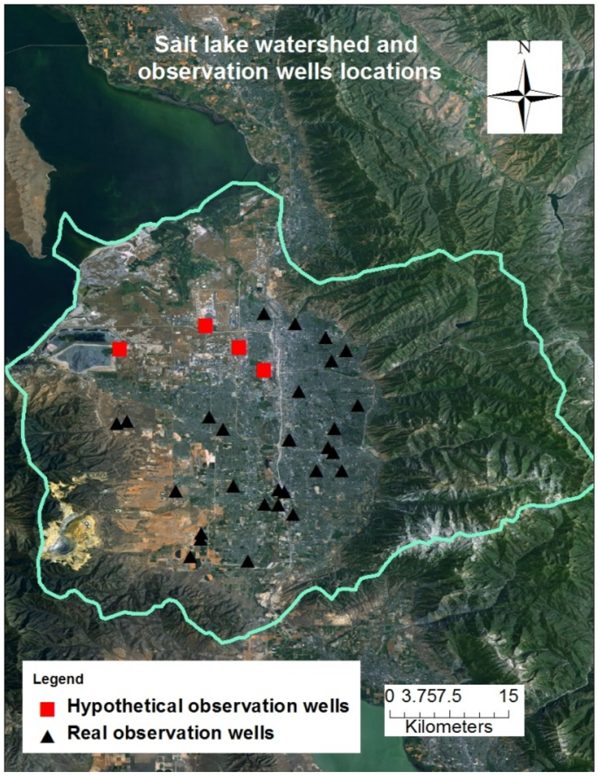

Fig1- Salt lake watershed and the location of observation wells

The groundwater level measurements in USGS are as "water level below land surface". So, if we want to produce the groundwater elevation in each station, we need to subtract that value from ground surface elevation of the station (observation well).

It is worthwhile to mention that there are some stations with negative values. The negative value for "water level below land surface" means that station is located in a confined aquifer. We did not use these stations because we wanted to investigate just unconfined layer in our study area.

There are 29 stations with complete data in the region. Because of not existence any station in northwest of our region, which had decreased the accuracy of our results, we defined 4 hypothetical stations in those area. Using map of water body in the region, we defined those 4 stations near some specific ponds or rivers. So, we can assume that depth of groundwater in those 4 hypothetical stations is 0 throughout 10 years of study. Therefore, we used the data in 33 stations (29 real and 4 hypothetical) to obtain our desired maps. Fig 1 shows the locations of real and hypothetical stations in our study area.

2- Region's digital elevation model (DEM):

Using DEM file of our study area which represents the earth's surface elevation, we can produce the map of groundwater elevation from depth of groundwater map or vice versa. This data can be achieved by two methods. First, we can have DEM file from National Elevation Dataset (NED) and second, we can use Utah GIS Portal website. We used the second dataset for downloading DEM file of our watershed.

3- Salt Lake Watershed boundary:

We can obtain the map of the boundary of our study area by two methods; first, using Watershed Boundary Dataset and second, using CUAHSI Hydrologic Information System. We used CUAHSI to obtain the boundary of Salt lake watershed.

Methodology

We used ArcGIS for investigating the groundwater conditions in our study area. After collecting observation wells data from USGS, we employed "interpolation" tool in ArcGIS and used DEM file to produce groundwater elevation and depth of groundwater maps throughout the region. In this study, we used the Kriging method for interpolation. However, the other interpolation methods might obtain different results. Also using the "subtract" tool in ArcGIS, we are able to obtain the map of differences in groundwater elevation for our desired time periods. In other words, by comparing the groundwater table in different times, we can determine the decrease (or increase) in water table in different time periods and specify the areas which have the most increase or decrease in water table in the region in our desired time periods. At last, using the capabilities of "classify" we can specify our desired areas in the maps.

Results and discussion

1- Obtaining interpolated surface of groundwater elevation and depth of unsaturated zone:

There are two procedures for addressing this objective. 1- Using data in USGS website (water level below land surface) which is in fact the depth of groundwater in each station and then interpolating these data for the entire region and finally subtracting that interpolated depth of groundwater map from DEM file to produce the interpolated groundwater elevation map. 2- Subtracting the depth of groundwater in each station from ground surface elevation of that station to produce the groundwater elevation in that station and then interpolating obtained data for entire region and finally subtracting that interpolated groundwater elevation map from DEM file to produce the interpolated depth of groundwater map.

Although it seems more physically correct to interpolate groundwater levels directly, the results of procedure 1 were more reliable for our study area and we used that procedure for the rest of our study. Figure 2 shows the map of depth of groundwater (depth of unsaturated zone) in salt lake watershed in year 2011. Figure 3 shows the map of groundwater elevation in year 2011 which has been obtained by subtracting Fig 2 from DEM file of the study area.

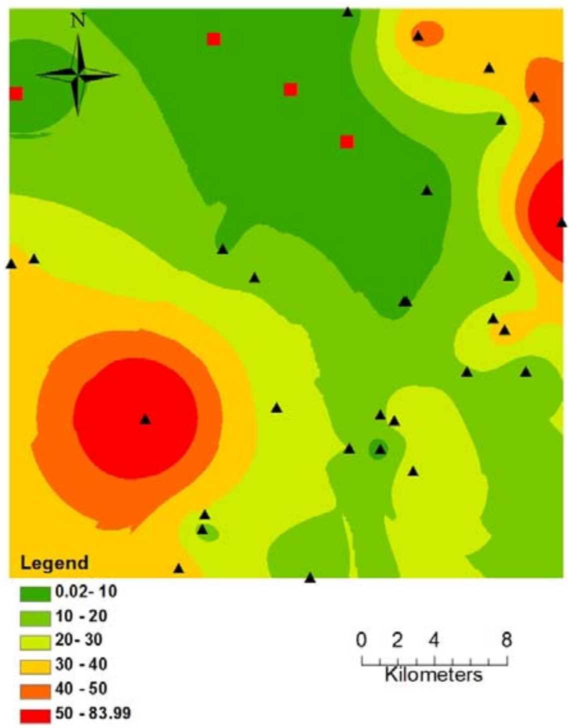

Fig2- Depth of groundwater (m) in year 2011

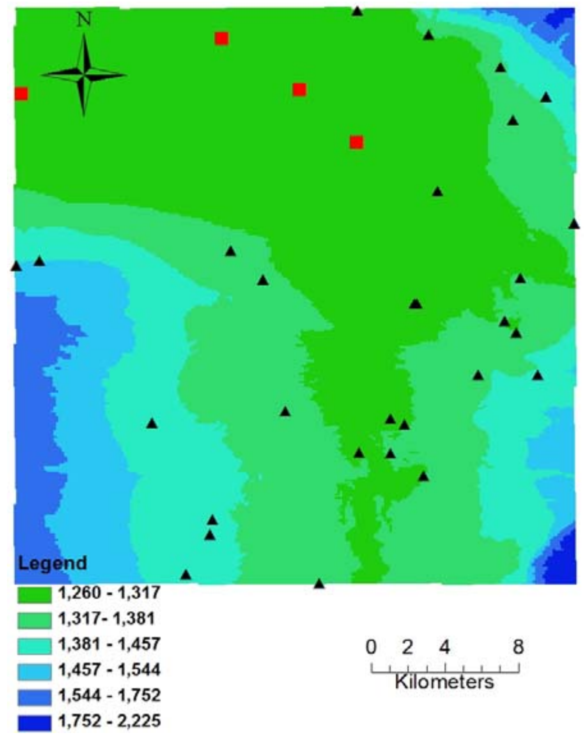

Fig3-Groundwater elevation (m) in year 2011

2- Specifying the critical areas

The critical areas are defined as the regions with decrease in groundwater table more than a certain critical value. We have defined two kind of critical values; yearly critical value, and 10 years period critical value which are 1m and 4m, respectively.

In other words, we consider a region as a "critical area" when the decrease in groundwater table in that area within 1 year is more than 1m or within 10 years is more than 4m. We have defined these critical values considering the groundwater fluctuations in our study area from 2001 to 2011. In fact, each region can have a special critical value based on the regional groundwater conditions in that region.

For specifying the critical areas based of yearly time period, as an example, we have considered the groundwater elevation maps for years 2001 and 2002 which can be achieved in objective 1. After subtracting groundwater elevation map of year 2002 from 2001, the map of yearly difference in groundwater elevation (from 2001 to 2002) is achieved. Fig 4 displays this map in which the regions with decrease in groundwater more than 1 m (critical areas) have been specified with red color. If we had access to a complete data for extraction wells locations, we could specify the wells in those critical areas. So, it might be a good advice for water managers to try to decrease pumping from wells located in critical areas.

It is worthwhile to mention that Extraction wells locations are the kind of data which are not achieved easily by internet. Although, we found some data for major wells and springs in our study area from Utah Geological Survey website, we did not considered that as a complete one and consequently we did not use it in our study.

Similarly, for specifying critical areas based of 10 years time period, we have considered the groundwater elevation maps for years 2001 and 2011. After subtracting groundwater elevation map of year 2011 from 2001, the map of difference in groundwater elevation from 2001 to 2011 is obtained. Fig 5 displays this map in which the critical areas with decrease in groundwater table more than 4 m have been specified with red color.

Therefore, considering both Fig 4 and Fig5, we can infer that the southwest of our region is the area with the highest decrease in groundwater table, probably due to excessive pumping from extraction wells in that region.

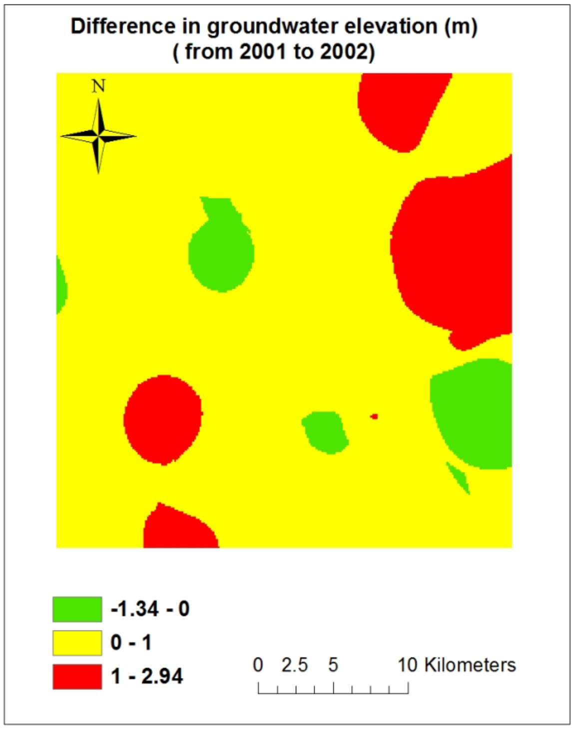

Fig4- Critical areas considering yearly time period from 2001 to 2002 (red regions)

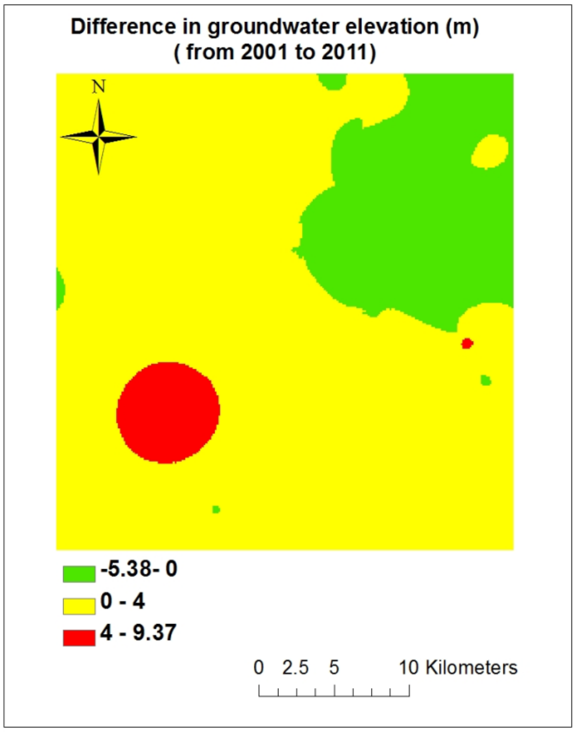

Fig5- Critical areas considering 10 years time period (red regions)

3- Specifying the regions possibly affected by artificial recharge system:

In addition to specifying the regions with the highest decrease in groundwater elevation, we can also specify the regions with the highest increase in groundwater elevation. These areas are possibly affected by some artificial recharge system in the study area. Artificial recharge which might be implemented by regional water managers is the practice of increasing by artificial means the amount of water that enters a groundwater reservoir. This includes, for example, direction of water to the land surface through canals and injection of water into the subsurface through wells.

Fig 6 is again the map of difference in groundwater elevation from 2001 to 2011 in which we have specified the regions with increase in groundwater table more than 2m with dark green color. That area in northeast of our region is considered as the region possibly affected by some artificial recharge system from 2001 to 2011.

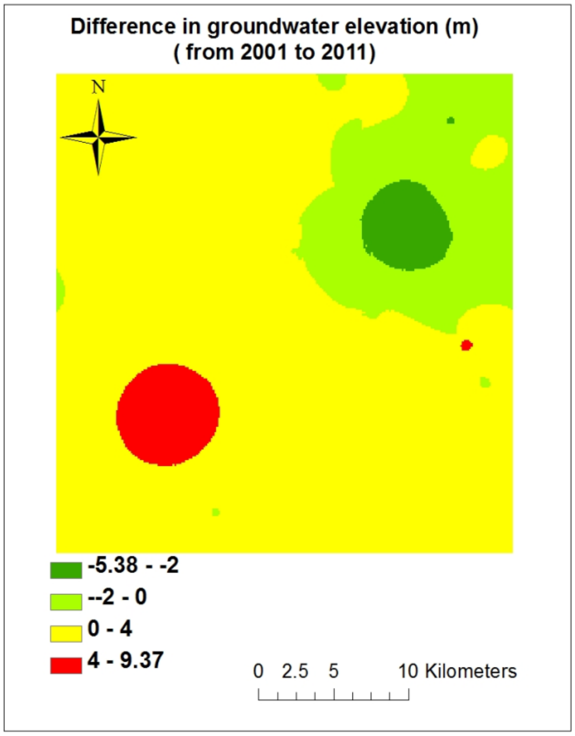

Fig6- Regions possibly affected by some artificial recharge system (dark green regions)

4- Specifying the regions with high pumping cost

Pumping cost for an extraction well is a function of the lift of groundwater to ground surface. In fact, it is a function of depth of groundwater in that well. So, for determining the cost of pumping, we need to use the map of depth of groundwater which was achieved in objective 1 (Fig2). Based on the groundwater conditions in our study area, we have defined "high depth of groundwater" as 30 m. It means we consider the areas with depth of groundwater more than 30m as the regions in which the cost of pumping groundwater is higher than the other parts. Fig 7 shows the map of depth of unsaturated zone (depth of groundwater) in year 2011. The regions with high pumping cost have been specified in this figure with red color.

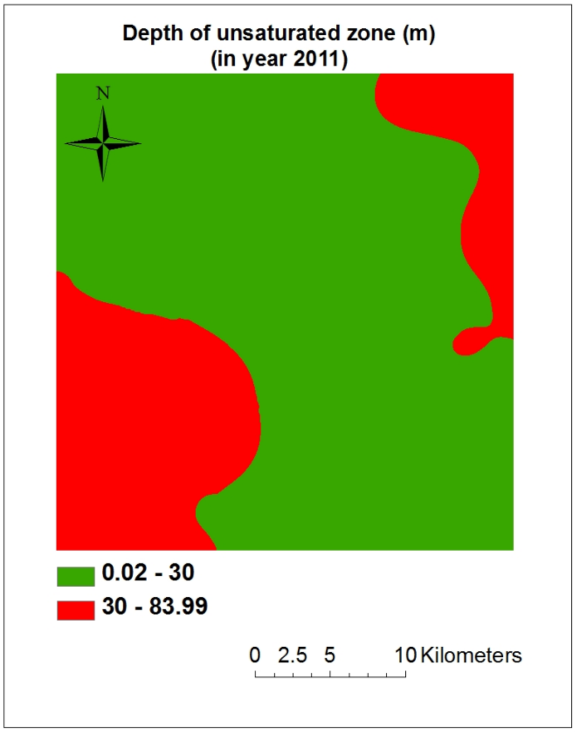

Fig7- Regions with high pumping cost (red regions)

References:

Utah GIS Portal http://gis.utah.gov/download

Utah Geological Survey http://geology.utah.gov/emp/geothermal/wells_springs_database.htm

USGS groundwater data http://waterdata.usgs.gov/nwis/gw

CUAHSI Hydrologic Information System http://cuahsi.org/