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Assessment of Groundwater Levels in the Texas Hill Country

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Abstract

With the state of Texas facing one of the worst droughts it's seen in history, the Hill Country Alliance (HCA) is seeking a way to assess and express water level conditions that is easy to understand. This project was created to map and display groundwater level conditions, expressed as percentile values, within the Texas Hill Country based on criteria set by the HCA.

To accomplish this task, Bobcat Geospatial Solutions (BGS) collected well data from the United States Geological Survey (USGS), Texas Water Development Board (TWDB), and participating groundwater conservation districts of the Texas Hill Country. County, urban areas and road layers were collected from the Texas Natural Resources Information System (TNRIS) with the purpose of HCA using these layers to easily identify well locations. HCA requested that we collect well data that met criteria of 40 or more measurements within a 10-year span and are currently monitored by the groundwater conservation districts. We were able to compile the records of qualifying wells into a data layer for our map. The end result is a map that displays qualifying wells based on their percentile value, which reflect recent groundwater level conditions in the HCA study region. The results of this project will be the first step in the HCA's plan to further expand their research on producing a program to calculate and present a percentile assessment of groundwater conditions.

Introduction

Summary

The Hill Country Alliance (HCA) is a nonprofit organization whose purpose is to raise public awareness and build community support around the need to preserve the natural resources and heritage of the Central Texas Hill Country. To assist in their efforts to preserve water quality, water supply and natural beauty of our community, HCA requested that Bobcat

Geospatial Solutions (BGS) research groundwater in the area, specifically historic water levels and geographic data on water wells in the region.

BGS collected and collated water well data from the United States Geological Surveys (USGS), the Texas Water Development Board (TWDB), and local groundwater conservation districts (GCD) to initiate the HCA's groundwater research project for 17 counties that comprise the Texas Hill Country. We used collected data to create an online color-coded Geographic Information Systems (GIS) map-product website for the Hill Country Alliance (HCA). The map-product expresses recent well water elevations as a percentile value using graduated color points. The Hill Country Alliance (HCA) will host, maintain, operate, and augment the interactive map on their website.

Problem

Although some raw data exists for well levels on a few websites, none provide a color-coded map-product that charts long-term changes in water well levels for the 17 counties (Burnet, Mason, Llano, Kimble, Gillespie, Blanco, Travis, Hays, Comal, Bexar, Kendall, Medina, Uvalde, Bandera, Real, Edwards, Kerr, and Edwards) that encompass the Texas Hill Country. Our research will assist HCA's study of the ongoing drought to determine its effects on the water supply in this region. HCA plans to use our data to eventually create a real-time study of water well levels in a more interactive map.

Literature Review

Since the 1960s, Geographic Information Systems (GIS) have evolved to store, manipulate, analyze, and present data. These capabilities make GIS an excellent tool to illustrate effects of human activities like pumping and natural events such as droughts and floods on groundwater levels. GIS can utilize groundwater measurements that have been collected over a

period of time, and present them as maps and models that can help raise awareness about water conservation and protection.

For example, in a 2001 drought analysis, Taylor reports how the USGS in Pennsylvania calculated 70-year-old groundwater-level measurements in GIS to determine how long water rationing was necessary after the state began to experience some precipitation (2001). As the drought in Central Texas continues, the HCA needs ways to easily show water levels in wells and communicate future sustainability needs to stakeholders in the area.

As the population in Central Texas continues to expand with new development, the increasing number of residents will need to pump more water from wells, which will deplete water supplies especially without sufficient recharge. The HCA needs ways to educate stakeholders on trends in groundwater levels for water management purposes. GIS has been used worldwide to illustrate the need for water use regulation.

In India, GIS was used to assess the effects of irrigation projects on water levels in order to develop strategies for groundwater management (Chowdary 2003). Using GIS, they were able to create models and display data layers that show the distribution of recharge rates. The illustrations that were created helped water professionals set the initial management framework. Our data layers will enhance the HCA's database of research to help create strategies to manage the diminishing groundwater for the Texas Hill Country. As the groundwater in the Hill Country becomes depleted, we will undoubtedly begin to experience problems with water quality. Water well studies have been used to help predict areas of possible groundwater contamination.

In Jordan, researchers produced maps to display where Azraq groundwater basin was likely to become contaminated (Al-Adamat, Foster, and Baban: 2003). They were able to incorporate other software and hydrography layers into GIS to create vulnerability layers both to

illustrate the risk and to determine ways to avoid contamination. Not only can GIS display collected information about a certain aquifer, but it can also manipulate collected measurement data from one location to calculate water levels another.

At current pumping rates, studies show the Edwards-Trinity Aquifer level will continue to fall by about a foot a year (Wilder 2010). However, affects on individual wells and springs is still unknown because current "groundwater models work on mile-by-mile grids." More studies are needed to determine the specific effects continued and increased pumping will have on ground and surface water levels throughout the Hill Country. Better GIS models will help conservation agencies such as HCA better communicate the future of groundwater sustainability to various stakeholders.
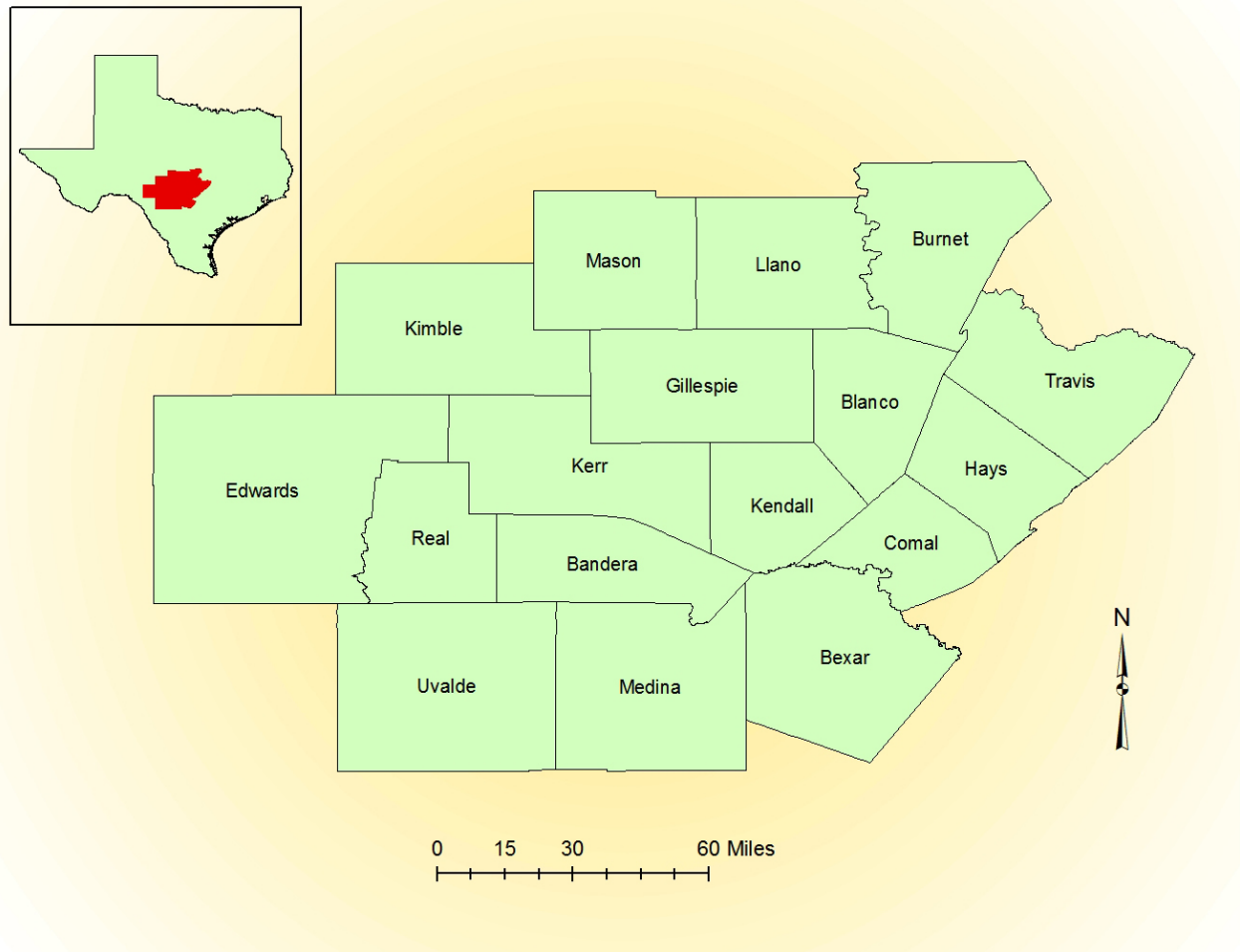
Figure 1. Seventeen County Hill Country Study Area

Data

Bobcat Geospatial Solutions acquired well data for the Texas Hill Country that meet HCA's stated criteria: measurements for ten or more years, more than 40 water level counts, and continuous monthly readings. We collected shapefile layers for county boundaries, roads, and urban areas from Texas Natural Resources Information System (TNRIS) (Table 1). We created a layer for well location by placing latitude and longitude degrees in the "Display X, Y Data option" in ArcGIS 10, which BGS used to calculate the data into a spatial diagram.

Table 1. Data Layers and their sources. [1]

Layer	Source
County Boundaries	TNRIS
Roads	TNRIS
Urban Area	TNRIS
Wells	BGS

[1]Abbreviations: Texas National Resource Information Systems (TNRIS)

Methods

BGS's project began with a search of the United States Geological Survey (USGS) and the Texas Water Development Board (TWDB) (Figure 1) online databases to find wells that met HCA's criteria. We collected the Texas State Well Number, dates of measurement, and depth of water for each well that met HCA's qualifications onto an Excel spreadsheet (Figure 2).

Figure 1. Descriptive Data for Wells

Figure 2 Well Data Copied into Excel

In the meantime, we emailed all the local groundwater districts in the Texas Hill Country

and requested data for wells that they monitor at monthly regular intervals. After a couple of

weeks, we sent a second email to districts that had not yet responded. Most groundwater districts

wrote that they do not monitor wells frequently enough for our research. We collected well data

from the few districts that record water levels monthly, sorted, and cross-referenced it to ensure

we included all wells that met HCA's criteria even if it meant combining two or more sources

(Figure 3).

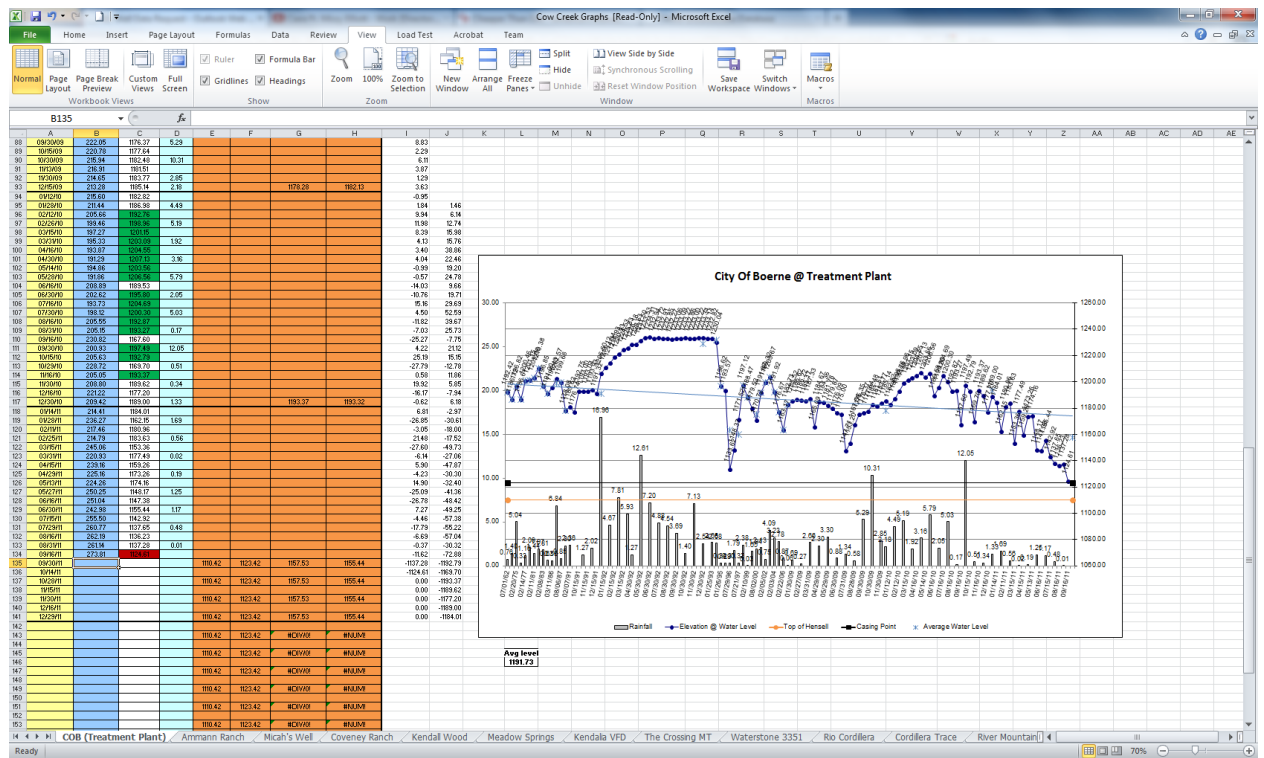Figure 3 Data Received from Cow Creek Ground Water District

To create our map-product, we obtained county boundaries, roads, urban areas, and

bodies of water from the Texas National Resource Information Systems. After uploading the

relevant files, all roads, and urban areas in the Texas map layers were clipped down to the 17

Hill Country counties using an SQL equation. All remaining data was organized into layers.

We organized the data (Texas State Well Number, depth of water, elevation, water elevation, latitude, longitude, county, and the providing aquifer) for qualifying wells into Microsoft Excel spreadsheets. Next, we imported all these spreadsheets into ArcGIS software. After we imported the Excel spreadsheets into ArcGIS, we used decimal latitude and longitude to geocode all the well locations.

We calculated percentiles based on all of the water elevations collected for each well using the Wessa.net, a website provided to us by the HCA staff. For the map, we only used the percentile of the most recent measurement. The well locations shapefile expresses those most recent measurements in graduated color-coded points that reflect a range of percentiles (<10, 11-24, 25-74, 75-90, and >90). Percentiles split a set of ordered data into hundredths based on rank. For example, if something is ranked in the 50 percentile, 49 rank above and 49 below.

Using ArcGIS, we hyperlinked a separate Excel spreadsheet that contains all collected data for each well location so the user can easily click on a well's point and find historical measurements and geographic data for that location. We created the map-product created in ArcGIS, then imported it into Manifold, a GIS application that enables us to easily put the map-product on the web. We exported shapefiles into KMZ files so HCA will be able to build a real-time server for public use at a later date that will maintain the measurement records and calculate percentile of the well's most current water elevation.

Results

HCA plans to use our study as a springboard for their groundwater research in the Hill Country region, investigations that are needed to educate stakeholders during this time of drought coupled with a rise in population. We noted in our study, all but a few of the most

recent well measurements are extremely low (.01 to 2 percentiles) compared to their historical elevations. There are no discernible patterns in the location of the four wells with the highest water elevation (more than 50 percentiles). Wells that qualify for the study are not distributed evenly throughout the geographic area because only seven Hill Country GWDs record water levels on a monthly basis.

Discussion

We originally collected data on over 400 wells that met the 10-year and 40-measurement criteria; however, because most GWDs are too understaffed to collect monthly measurements, we had to disqualify most. Only 59 wells in seven counties are measured monthly. Conversely, many currently monitored wells with 40 or more measurements do not meet the 10-year criteria.

As we worked to complete this project, it became clear to all group members and our client that it will be extremely difficult to establish and maintain a real-time map that will continually display current measurements for wells across the Hill Country. We would be able maintain the database needed to display all of the most recent measurements for qualifying wells because there is a delay between the water level collection and data submission to their databases. Some districts had valuable data and information (regardless of whether or not it was used in the final product) while others led us to online databases already explored by our group.

Although most wells are currently extremely low (.01 to 2 percentiles) compared to their historical water elevation, four wells located in clusters of wells have percentile values of over 20. This pattern is significant and is deserving of further investigation. However, any spatial pattern identified in this project is limited by the lack of available historical data (a 10-year or longer series) or regular monthly elevation readings for many Hill Country counties.

GIS limitations were experienced during the final stages of the project. With more time, we would have created an animation of the water level changes over the years to perhaps find a pattern in the water levels.

Conclusions

The group agrees that the project would have been better we had more time and data. Frustrations stemmed from limitations of the project as well as confusion over the best way to approach it. We spent most of our time simply gathering and sorting data from various entities. After we collected data, it was difficult for everyone to continually contribute to the progress of the project since we could not split up the data. The need to have the data on just two spreadsheets also made it difficult for everyone to participate in the GIS and map creation stage.

The group was disappointed that the project had to little to do with GIS; it was much more about data collection. Afterward, data needed more statistical than geographical analysis. Since only seven groundwater districts monitor any of their well levels monthly, our data wasn't spread across all 17 counties. With so little data, it appears the project has little geographical significance and no real pattern in the results. The only discernible pattern is the lack of data for certain counties and an over abundance for others.

Despite the setbacks and limitations of the project, it did prove to be valuable learning experience. We all received extensive experience with public speaking, writing, and producing documents that will be required in the work place. We learned how to conduct percentile analysis, hyperlink Excel spreadsheets to GIS layers, and create a website. All these things will undoubtedly prove very useful in our future endeavors, either in academics or careers.

Appendix I

Metadata

See CD-Rom

Participation

Charles Hill – Webmaster/GIS Analyst

- Completed part of "Literature Review" section of the proposal
- Completed "Future Work" section of the progress report
- Created logo
- Created website
- Assisted in creation of the poster
- Collected well data for Edwards, Real, Uvalde and Medina county
- Organized well data provided by the Central Texas GCD
- Data dictionary
- Converted ArcGIS 10 layers to kmz files (working on it right now)
-

Sarita Hedgepeth – Assistant Manager

- Collected data for Bexar, Travis, Hays, Medina and Comal counties.
- Created the methodology, timeline and budget section and contributed to the literary references section for the Proposal and Progress Report
- Wrote the ongoing work section and provided the screenshots and preliminary geocoding map for the Progress Report.
- Created the skeleton PowerPoint for the initial proposal, progress report and final proposal presentations.
- Refined datasets for Cow Creek, Hays Trinity, Central Texas-Ellenburger Group and HGCD while removing all erroneous data from our historical files.
- Collected, sorted and cleaned I consolidated everyone's work into the uniform spreadsheets needed to progress to the percentile and map creation stage.
- Teresa and I split the work needed to run the percentiles on the wells that were to be used in the final product.

- Made separate spreadsheets for all the wells that were going to be converted into shapefiles.
- Reworked the shapefiles because they had the wrong projection but they were done.
- Inserted all the data into the separate spreadsheet files that Scott created to hyperlink in ArcGIS for the final map.
- Created the additional files that were needed for the hyperlinks because they had been overlooked.
- Created the "About This File" pages for all of the Excel Spreadsheets I had in my possession.

Scott Lindsay – GIS Analyst

- Contributed to the data collection.
- Helped email the groundwater districts the first time around.
- Produced the map documents.
- Completed the manifold section.
- Made the hyperlinks.
- Wrote metadata

Teresa Hobby – Manager

- Contributed to data collection
- Emailed groundwater districts
- Responded to groundwater districts
- Wrote/compiled most of the Proposal, Progress Report, and Final Report
- Corresponded with Raymond Slade
- Calculated percentiles
- Refined datasets for groundwater districts
- Created hyperlinked Excel files with well data
- Assisted with poster

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