Terri Breeden  
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**Geographic Information Systems and Remote Sensing in Hydrogeology**

Hydrogeology is the study of groundwater movement through soil and rock. Fresh water is the most valuable resource on Earth, as it is very limited in quantity and quality. It determines all factors for growth and development of a culture and society. If freshwater is not available, it is very difficult to settle in that environment in regards of meeting adequate agriculture and livestock needs as well as human dietary needs. If water comes up relatively high in the soil column it will limit infrastructure growth, such as the construction of skyscrapers, subways or basements in houses, as it may be more prone to flooding. Through geographic information systems and remote sensing, scientists can better determine the hydrogeological movements of groundwater. Creating these models will help communities prepare for flood and drought conditions, avoid water resource exploitation, and construct well-built infrastructure. This is particularly useful in areas that have little groundwater recharge which may cause restrictions on water usage. It can help determine areas where conservation efforts should be directed to limit urbanization and pollution and where to build certain landscape and architectural features.

Geographic Information Systems has a wide range of values for hydrogeology all over the world. It allows us to analyze, interpret and visualize many features that are not always visible on the surface. Many studies have used ArcMap with a variety of other modeling programs. Some of the most common platforms for storing and analyzing hydrogeological data include MODFLOW, Rock Ware (Arc View), and watershed modeling software (WMS). In order to develop a relevant model, tremendous amounts of information must be collected, with much of it being in the field. ArcMap is an ideal software program for collecting and storing hydrogeological data because it can provide spatial resolution whereas other programs such as CAD cannot. Some of the vital information needed includes rainfall amounts, groundwater recharge rates, lithology, density, slope, depth to groundwater and water quality. Some of these data can be collected using Digital Elevation Models (DEM) and weather station records, but most is composed from vast quantities of borehole records. The most valuable tools within ArcMap are Kriging and Triangulated Irregular Network (TIN). Kriging is useful because borehole data can only reveal so much information within a small distance, as it is a small point in the larger landscape. This method will interpolate unknown points from nearby samples, and develop a semi-variogram to predict possible errors. The TIN method takes the median value between two known points and is considered the most conservative and innovative method to interpolate data. Another valuable aspect involves the use of Arc Scene. This program allows the user to make three dimensional models of the area of interest. The 3D models provide a much better depiction and visually aesthetic view of the hydrogeological structures.

Remote sensing is the collection, interpretation and analysis of spatial data without physically touching the area. In regards to hydrogeology, this data is collected using active remote sensors on satellites. It is extremely beneficial in locating rock fractures. These cracks can be extracted from satellite images and will deduce the infiltration rate for groundwater recharge. The location of interest and the resolution of data needed will determine which satellite in which to receive data. For instance, a study took place in India which used Indian Remote Sensing Satellites (IRS) and Linear Image Self-Scanning (LISS) III from bands 2, 3, and 4 at a scale of 1:50,000. Upon further investigation a higher resolution was needed and 30 meter Advanced Space borne Thermal Emission and Reflection Radiometer
(ASTER) imagery was used instead (Prabu, 2013). Other commonly used sensors include the Enhanced Thematic Mapper (ETM+) found on the LandSat 7 satellite (30 meter pixel size) and the SPOT 4 satellite (10 meter pixel size) which records vegetation data.

The combination of using both Geographic Information Systems and Remote Sensing techniques and data has proven to be an invaluable resource in the field of hydrogeology. The immense amount of data currently available, along with the information that can be collected at individual sites and boreholes gives the user a tremendous amount of control on how to interpolate each layer. For example, by looking at the vegetation data from the SPOT 4, one can interpolate the climate, rainfall and relative soil types in the area, thus deducing where potential groundwater areas of concern may be. The hydrogeologist can then pinpoint exact areas to target for borehole analysis. By using these technologies simultaneously, the scientist is saving both time and money. All of this information can be digitized or rasterized into layers that can be incorporated with other maps. These maps can point out areas of concern, areas to be considered for conservation land, or if civil infrastructures can be built in a certain area. Together these tools allow scientists to make wise environmental, management and natural resources decisions.

The technology and tools behind Geographic Information Systems and Remote Sensing seems to be ever changing. Hydrogeologist are using many different modeling programs such as the software suites mentioned above, and some are even creating their own programs. As a relatively new scientist in this field, I find it overwhelming. I wonder which models are worth learning to use and which are not, but also seems that each model varies and you must work with the program that will provide the most accurate results. With hydrogeology, there is so much information needed to precisely interpolate a map. It seems slightly more difficult because you are working with a surface that can not necessarily be seen. The creation of a more universal, user friendly database would be ideal for hydrogeological studies around the globe. Groundwater can behave in odd ways at times, thus Arc Scene seems to be one of the most valuable models to use as it gives a three dimensional visualization of the ground beneath our feet. As many studies noted, the results are only as good as the data, especially in reference to the number of samples, data, or boreholes, the experience of the hydrogeologist, and resolution of satellite data. Unfortunately, this is also a down side of this technology in this field. Data collection and analysis can be very costly and time consuming. It would be ideal if improvements could be made in remote sensing data collection. The development of a sensor that can monitor groundwater remotely around the world would have incredible reaches in hydrogeology. As technology gets more advanced and innovative, I can only imagine the use of these models to get easier and more user-friendly.

Annotated Bibliography


The authors of this paper looked at using remote sensing and GIS technologies to map potential areas of groundwater in the Sinai Peninsula, Egypt. This area is 94% arid desert and water is a valuable resource in this climate. Elewa and Qaddah created thematic layers looking at rainfall, net groundwater recharge, lithology or infiltration, lineament density, slope, drainage density, depth to groundwater, and water
quality. By layering each theme, the authors were able to determine the areas of highest groundwater potential infiltration. Modeling programs such as GIS, RS, WMS, and WSPM provided valuable tools to create these maps. High and low potential areas were fact checked and the model proved to have higher confidence intervals. This paper is able to aid decision makers in the Sinai Peninsula in making sustainable choices in groundwater protection zones and usage.


Velasco et al. developed an innovative paper in regards to hydrogeology and incorporating new technology. The paper stresses the importance of quality and quantity of data and model a case study in the Besos River Delta, Spain. This area is very urbanized and the local groundwater quality has been affected. Previous models only gave a two dimensional visualization. By incorporating many different modeling programs into Arc Scene, the authors were able to create three dimensional maps. Although the process is very tedious and requires knowledge of multiple modeling programs and databases, the advantages surmount. This study provides a methodical technique to model hydraulic characteristics of sedimentary bodies, thus providing a better understanding of hydrogeological processes.


The authors of this paper used lineament mapping techniques to show the correlation between well productivity and the distance to identified features. The case study took place in India with objectives to produce a regional lineament map from remotely sensed data, determine hydrogeological features by integrating with DEM and to analyze the study area with different lineament maps. The study used IRS, LISS, and ASTER satellites and sensors for lineament interpretation. The authors provided an effective method for revealing points of groundwater recharge and discharge, flow and development. This method is also capable of extracting lineament information in dense inaccessible tropical forests. It is suggested that highly detailed geo-electrical surveys for groundwater potential are performed in future study areas to assist in strong data analysis processes.


The authors used active and passive remotely sensed data to study soil moisture content from more than 200 stations around the world to determine reliability of specific soil moisture products. The authors used eleven soil moisture data sets, with two being remotely sensed, one model prediction, and eight in-situ observations. The primary sensors used included ASCAT, from the EUMETSAT satellite, and SMOS, with L through K bands providing the most vital information. The study determined the reliability of soil moisture within the first few centimeters of soil in near real time from the ASCAT and EUMETSAT, weather station predictions, and the modeled difference between direct and measured temperature data. Australia had the most encouraging results with fewer microwave interferences. Albergel et al. validate measurability of soil moisture variables, thus providing better weather forecast models for seasonal
climate variations, plant growth and carbon fluxes through statistical analysis and correlation studies. This analysis paves the way for future studies. Upcoming missions will allow thorough investigations of snow mass and vegetation parameters, which will provide better weather modeling tools which contribute to hydrogeological factors.


Chenini and El May discuss how artificial aquifer recharge may be a viable solution for areas with depleting groundwater resources. The authors looked at a case study in Tunisia by analyzing multiple layers in a GIS database. A thematic groundwater recharge map was created by layering historic rainfall data, watershed drainage density, surficial geology and aquifer boundary conditions. The Theissen method was used to interpolate specific areas, with certain criteria being weighted as it has more of an impact on groundwater flow. Other features included lithology, permeability, fractured outcrops, lineaments, and piezometry. It is suggested that surface water systems in certain areas can help replenish depleted groundwater supplies. The map determines which areas would be most beneficial and have the most impact on recharge zones. The author concludes that this method can be used in other arid regions but accurate maps are heavily determined by thorough investigation and data collection.


Brunner et al., discuss the technology available from remote sensing and how it has contributed to the field of hydrogeology. Historically, groundwater models were determined using point data obtained from a weather station, a gauging station or borehole. Remote sensing allows spatial data to be processed to form zones or layers. This paper explains many of the types of remote sensing data that is available. Surveys such as GRACE, DEM, LiDAR, GPS and SRTM data has vastly improved the quantity and quality of data. Two case studies were analyzed; one was in Botswana and one in China. An important aspect that the authors emphasize as “words of caution,” is the importance of ground truthing. If the data is not checked, the models produced are considered poor and unreliable. Unfortunately, ground truthing is often the most costly element in remote sensing analysis.