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MONITORING SYSTEM FOR WATER LEVEL IN OBSERVATION WELLS

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ABSTRACT

The phreatic level is the upper level of the free groundwater, with a pressure equal to the atmospheric pressure. The depth can vary according to the geological medium, ranging from several centimetres to several tens of meters, depending on the region. This level can be determined by measurements taken from the airplane, resisted determinations or the realization of a perforation in the ground to measure the depth of the water. In this document, a wireless monitoring system with level sensors is made in each hole in the ground or well. These measurements were transferred to a coordinator node through ZigBee modules, which are stored in an EEPROM memory. Once the data of several days of all the wells that are monitored are obtained, they are downloaded and processed in an interface developed in Matlab for further analysis.

Keywords: isolines, water level, node, XBee.

INTRODUCTION

Predicting the productivity of wells or finding changes in the flow of currents and springs is feasible with the data collected from the water table in a certain area. In other words, changes in the level of groundwater are evident. Measurements such as those made from an airplane and determinations by means of resistimeters or drilling, in which the depth of the water is shown, are generally used to determine the underground water table *(Andricevic 1990; Tsujimura et al.* 2007).

The system implemented for the measurement of the water table consists of a network of distance measuring sensors, distributed throughout a field. It has a coordinating node, which will request the depth information of the water table from the network nodes with sensors (Yussoff et al. 2010). The required data of each terminal node will be stored in an EEPROM, together with the date and time at which the reading was made.

Once the collected information has been stored for several days, the data is downloaded to the application made in Matlab for its corresponding processing of the information. In the interface, the data collected from the test of the monitoring days is displayed and additionally graphs such as hydrograph, the topology of the ground and the water table, equipotential planes and isoprofundy planes are generated (Saraf and Choudhury 1998).

BACKGRAOUND

Water Table

Basically, the water table is the upper level of free groundwater, which has a pressure equal to atmospheric pressure (Tsujimura *et al.* 2007; Tyler and Seliger 1978). In other words, the water table is the first layer of water found when performing a hole in the ground, as illustrated in Figure-1.

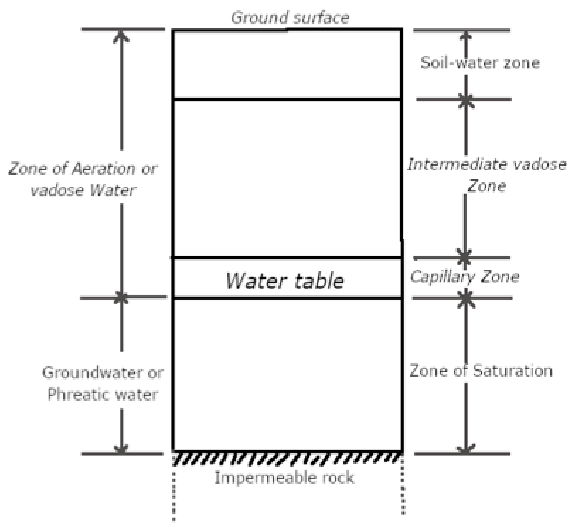

Figure-1. Vertical distribution of waters in the subsurface.

Measurement of Water Tables

The scoop used for the measurement of water tables in this investigation consists of measuring the distance from the surface to the water contained within the tube in centimeters (Figure-2).

Generally, an observation well can have a depth between 1.8m and 2.0m *(Tsujimura et al.* 2007; Waters *et al.* 1990). This group of wells are installed in such a way that they cover critical areas and possible influence of water recharge on the ground.

Rods, metal ribbons, ropes, floats, and the like, are used to carry out the rudimentary inspection in wells. The use of a network of distance sensors to measure the depth of each well is what we shall adopt with this work.

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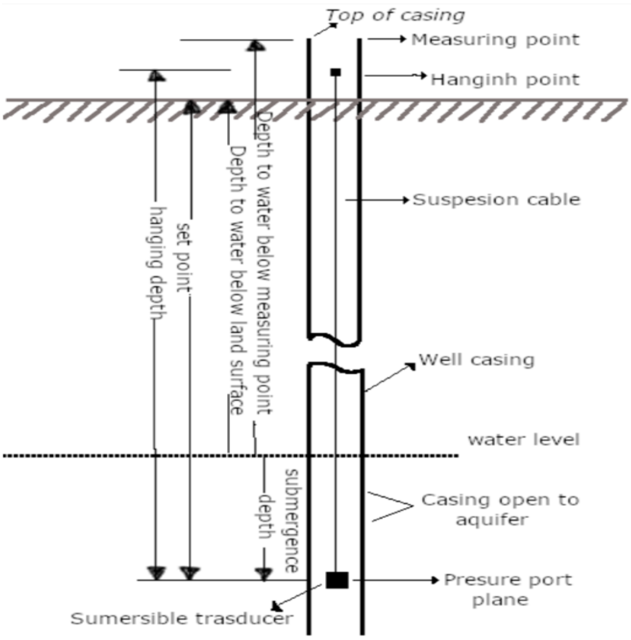

Figure-2. Well diagram for water level measurement.

Importance of Monitoring of Groundwater for a Hydraulic Design

For the design of a drainage system, it is essential to conduct a study which includes factors soil texture such as structure of soils, topography, porosity, water holding capacity, and, in particular, the permeability of these strata in a field, is essential for the design of a drainage system. The latter provides the identification of little permeable layers affecting the height of the water table within the profile water (Andricevic 1990).

Additionally, studying the groundwater that provides relevant elements in the design of drains is necessary for the solution of problems related to drainage. These data from each well can determine the height and direction of the water flow, showing critical areas (water saturation) or possible sectors with influence of springs of water.

Not only is the study used to solve agricultural problems but also in the study of civil works. For example, water table and the ground mark, partially, the dimensioning of the foundations for the work when it is required to raise a structure and they are used to generate systems of drains to evacuate water that saturate the soil. This is because the presence of water generates efforts resulting in a decrease of ideal characteristics to build (Kondratyev and Nikolsky 1970).

RESULTS

Installation Using Star Topology

A star-type topology network was created to implement the monitoring system for water table. This has a single node coordinator (C) and n nodes terminals (NT), as shown in Figure-3. Communication in this topology is centralized since each terminal device is attached to the network(Ashhar, Soh, and Kong 2017; Mayalarp, Vachirapol Poombansao, Thanachai Limpaswadpaisarn, Narisorn Kittipiyakil 2010; Smith and Pain 2009).

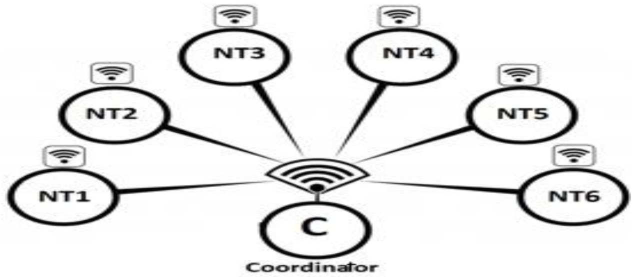

Figure-3. Sensors net.

Coordinator Node

It is responsible to establish the XBee network identifying the devices connected to the network (Saraf and Choudhury 1998), send requests for data acquisition to terminal nodes in the periods of initial setup, store the data collected and pass it on to the computer for processing and analysis, as shown in Figure-4 (Gastaldo 1992; Wang and Song 2011; Yussoff *et al.* 2010).

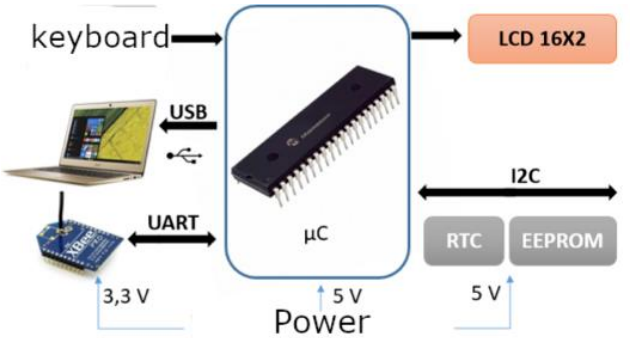

Figure-4. Coordinator node diagram

Terminal Nodes

Responsible for the measurement of the level in the observation wells and transmit it to the coordinator node (Figure-5) (Gastaldo 1992; Robert Faludi 2011).

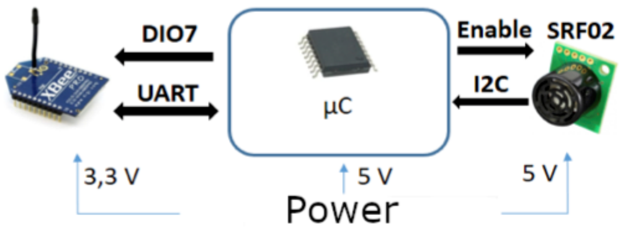

Figure-5. Terminal node diagram.

The level sensor was installed at the top of the assembled tube in such a way that it would not obstruct the reading with the walls of the tuve. This is why the pipe must be levelled in some way trying to make the sensor face down with the face of the sensor as vertically as possible. The sensor, which is protected by a black plastic structure, is assembled with a black ribbon. The device

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containing the sensor has a 2-inch diameter, which fits perfectly for pipes of the same diameter.

Interface

An interface, which allows the visualization of each one of the readings, is developed from the data collected by the coordinating node and the help of level sensors. This information can be seen in graphic and numeric ways (isobaths and isohypses representations) (Higham and Higham 2016).

Figure-6 illustrates the main display of the implanted interface where the readings done by terminal nodes can be evidenced, along with geographical coordinates and the menu of options for the graphics that are generated.

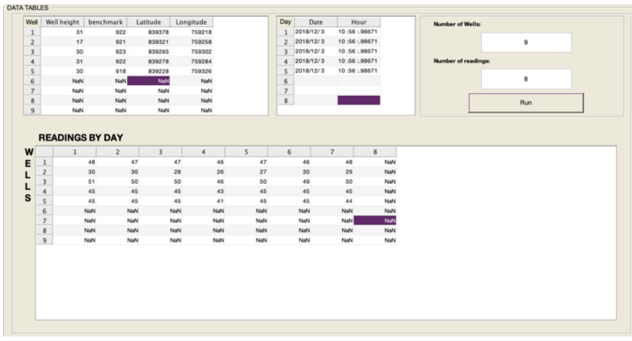

Figure-6. Interface performed on Guide de Matlab.

Functions

It has three (3) tables. The first one allows for the visualization of the pipe length that protrudes above the surface, the topographical elevation above sea level (metres), and the flat geographical coordinates where the well is located. These data are generated with the help of a GPS.

There is another table that shows the record of dates and hours at the time the central node requested to monitor the wells.

The last table specifies the distance between the sensor and water level; this, with help of the other two tables can determine the water level above sea level if required.

Additionally, the number of points that are used to do the interpolation of graphics is modified. This corresponds to the number of points that come from the interpolation, in this case it is the Kriging Universal Method (Kaymaz 2005; Lefohn *et al.* 1987).

The last function corresponds to the selection of the graphic. This function gives the user seven graphics that the software can generate from the data contained in it.

Kriging Prediction Method

It is a geostatistic interpolation method that is based on a set of points which are distributed on a surface with different Z values, in order to predict the behaviour of the neighbour or intermediate points. Thanks to this, a surface with the estimated values can be found (Liu, Shi, and Erdem 2010; Luo *et al.* 2012). The Kriging method adjusts to the equation 1.

$$Z(x_o) = \sum_{i=1}^{n} \lambda_i Z(x_i). \quad (1)$$

Where:
$Z(x_i) =$ The measured value in the location $n^o.i$
$\lambda_i =$ depends on autocorrection.
$x_o =$ the prediction's location.
$n =$ the number of measured values.

Kriging allows to find the spatial correlation to find intermediate points to the ones measured with the sensor network (Den Hertog, Kleijnen, and Siem 2006; Nielsen and Søndergaard 2002; Stanislawska *et al.* 2002).

Graphics Generated

There are numerous maps or planes that can be developed from underground water data, each one of the collected data must be processed in a way that allows an accurate outline of the graphics, this is, that the interpolarization will be performed by the predicting Kriging method to find intermediate points from their neighbors(Martin and Gorelick 2005).

Maps of Isobatas, Isohipsas

They are maps generated from the data collected from the observation wells. It connects the water levels of equal height by means of isobar lines, and generates arrows that represent the direction of flow. Figure-7 shows the implementation of the map.

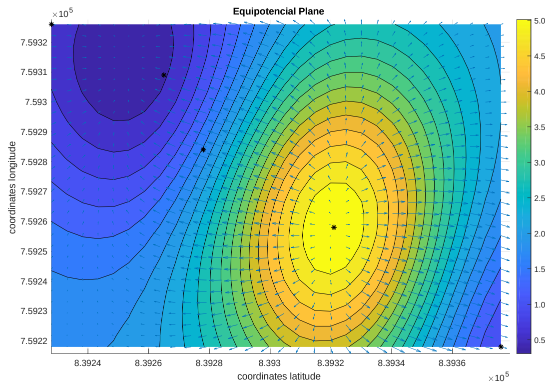

Figure-7. Map of Isobatas and Isohipsas.

Hyidrographs

A hydrograph is generated reflecting the behaviour of the wells over time. When the amount of groundwater in storage increases, the water table rises; when it decreases, the water table drops. This response to the water table to changes in storage can be observed in a hydrograph (Figure-8).

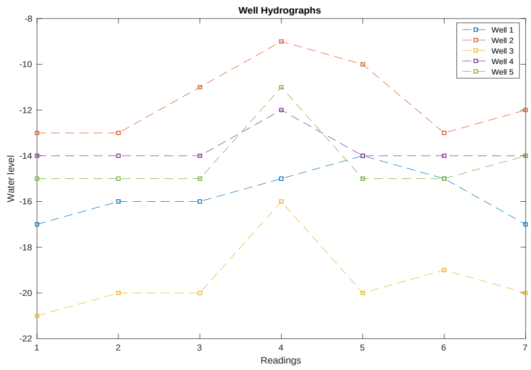

Figure-8. Hidrograph.

Topography of the Land and Water Table

The topology of the land and the water table are represented by a surface graph. Figure-9 will provide real information of the study area (height above sea level with their respective coordinates). This provides information on how the land and the water table to study are made up. It can offer if there are topographic slopes or accidents or, on the contrary, it is a flat terrain (Figure-9)(Nielsen and Søndergaard 2002; Stanislawska *et al.* 2002).

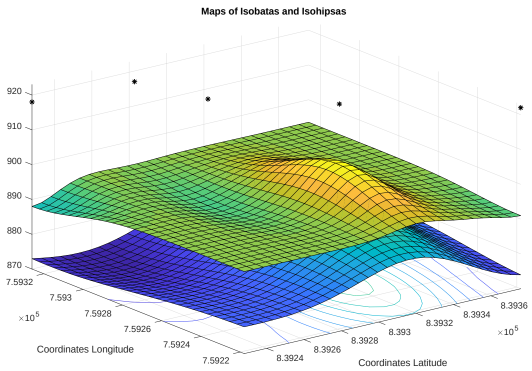

Figure-9. Topography of the land and water table.

CONCLUSIONS

The development of the water table monitoring system allows having an autonomous system that constantly monitors the depth variations of the water table of each observation well. Additionally, it will allow to design and implement the irrigation system for the study area.

It is possible to propose an application in Guide de Matlab, whose function is to perform the computational analysis of interpolations using the predictive method of Universal Kriging. This allows to obtain the intermediate points of the readings and generate a net that represents the surface of the water table and the land to be studied.

In order to have good communication between nodes, it is important that an installation of them is performed with the line of sight required for each XBee device.

Likewise, it is recommended, as further work, to make a larger sensor network with a topology different from the star proposed in this work. This will allow to evaluate the different configurations and select which is the most suitable to cover a little and enough area.

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