Investigation of Ground Water Reservoir in ASA and Ilorin West Local Government of Kwara State Using Geographic Information System.

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SUMMARY

Geographic information system (GIS) is an essential tool in hydrological investigations as they are essentially spatial in nature. The concept of hydrological investigation both surface and underground (subsurface) largely dependent on the availability of accurate information in order to arrive at quick decisions which in turn provide information on the hydro-geological characteristics of the area. The success of any water supply system can only be measured by how many people have access to clean and usable water. There is no doubt that access to quality drinking water is a serious issue in Nigeria. Asa river basin is not an exception. The main source of water supply to Ilorin is Asa water works, still people around there has no regular source to good water. Asa river basin is the host of Asa River the major source of recharge for the underground reservoir from which all the wells and boreholes in this river basin tap their water source.The results demonstrate that the integration of geographic information and traditional fieldwork provides a powerful tool in the assessment and management of water resources and development of groundwater exploration plans.

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1. INTRODUCTION

Water is a chemical substance with the chemical formula H_2O. Its molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. Water is a liquid at ambient conditions, but it often co-exists on earth with its solid state, ice, and gaseous state (water vapor or steam). Water covers 70.9% of the earth's surface, and is vital for all known forms of life on earth, it is found mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapor, clouds (formed of solid and liquid water particles suspended in air), and precipitation. Oceans hold 97% of surface water, glaciers and polar ice caps 2.4%, and other land surface water such as rivers, lakes and ponds 0.6%. A very small amount of the earth's water is contained within biological bodies and manufactured products.

Surface water is water collecting on the ground or in a stream, river, lake, wetland, or ocean; it is related to water collecting as groundwater or atmospheric water. Surface water is naturally replenished precipitation and naturally lost through discharge to evaporation and sub-surface seepage into the ground.

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology.(Ige and Ogunsanwo 2009).

Surface and ground water are two separate entities, so they must be regarded as such. However, there is an ever-increasing need for management of the two as they are part of an interrelated system that is paramount when the demand for water exceeds the available supply.

Water infiltrates into the soil through pores, cracks, and other spaces until it reaches the zone of saturation where all of the spaces are filled with water (rather than air). The zone of saturation occurs because water infiltrating the soil reaches an impermeable layer of rocks so that it is not able to penetrate any further into the earth. Two main forces drive the movement of groundwater. First water moves from higher elevations to lower elevation due to the effect of gravity. Second, water moves from areas of higher pressure to areas of lower pressure. Together these two forces make up the driving force behind moving groundwater which is known as the hydraulic head. (United State Geological Survey)

Ground and surface water are by no means disjoint, as knowing where surface water recharges groundwater and where groundwater flows supply surface water is an important aspect of the hydrologic cycle. Hydrogeology is especially well suited to GIS. Groundwater moves much more slowly than surface water, on the order of less than a meter per day up to perhaps a hundred meters per day, and is 3-dimensional in flow. In contrast, surface water flows much faster and is more two-dimensional. Groundwater flow is a function of geology and "head," the total potential energy at a location. Groundwater flows from higher head to lower head at a travel rate and flow path dictated by geology. Head values, geology, groundwater flow direction, even water table height and location of aquifers are among the quantities which can be presented spatially in GIS and used for analysis, management of water availability and water quality, and land use practices.

1.1 Statement of problem

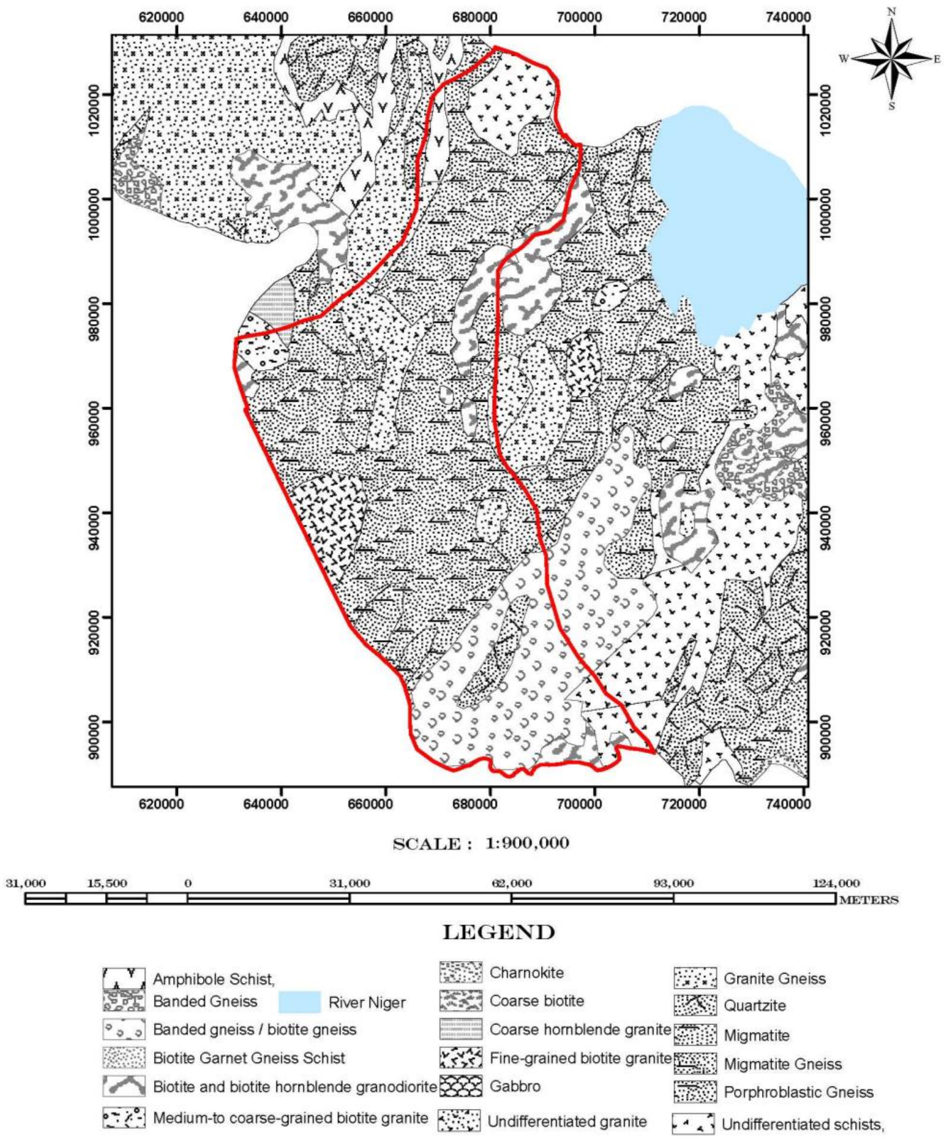
The main source of water supply to Ilorin is Asa water works, still people around there has no regular source to good water. Asa river basin is the host of Asa River the major source of recharge for the underground reservoir from which all the wells and boreholes in this river basin tap their water source. The standard water level of wells and boreholes in the area ranges from 16.07607 feet to 21.55505 feet and still some of the wells in the area are falling below this range either due to consumption by the inhabitants. This leads to the investigation of the underground water bearing reservoir using geographic information system techniques to know the volume of water remaining in the reservoir.

1.2 The study area

Asa river basin which lies within Asa and Ilorin west local government in Kwara state is located at the boundary of the state at the southwestern part of the state and it is surrounded by Moro local government to the north, Oyun and Offa local government to the South and Ilorin west local government to the East. The study area lies between latitudes 4^0 12'N and 4^0 29'N and longitudes 8^0 7'E and 8^0 42'E with an area of 5036.625km^2

1.3 Geology

The Asa river basin consists mainly of basement complex rocks of the older granite type and also the undifferentiated types. These rocks in many places have been greatly weathered in-situ and hence there are several pockets of weathered sand and sandy clay lenses within the basin, some of these pockets of weathered materials appear on the surface in several areas. The sand pockets form good aquifers for underground water which recharge the Asa river in the dry season.



Fig; 1.0 Geological map of the study area.

1.4 Climate

Asa local government area is within the transitional climate zone of Nigeria average daily temperature ranges between 26.28^0C and 31.95^0C. The dry season last from October to February while the Rainy season in the area begins towards the end of March and ends in October with two peak periods in June and September. The annual mean rain fall is about 1352.0mm.

2. METHODOLOGY

The step by step procedure adopted in carrying out this research is documented in this section

2.1 Database design

A database is an integrated, well-structured collection of data that can be accessed by different logical paths. Database design is a process by which the real world entities, their attributes and relationships are modeled in order to derive a maximum amount of benefits using a minimum amount of data. (Kufoniyi, 1998)

For this work, the spatial database which represents the location of spatial entities and their attributes is generated using two phases, namely:

- The design phase
- The creation phase

GIS database design process consists of three interrelated phases:

- Conceptual design
- Logical design
- Physical design

2.2 Database creation and implementation.

Point coordinates of the wells and boreholes were collected using GPS device the point coordinate is grouped in to wells and boreholes and corresponding attribute fields was created in ArcGIS 9.3 geodatabase using the ArcCatalog to store the point data and their corresponding attribute for the purpose of analysis.

Attributes of Well

OBJECTID	Shape *	Land_surface	Well_use	Hydro_ID	Hydro_Code	WaterLevel_M	Ftype	HydroID
3	Point	299	Agriculture	3	3128	23.287935	Water Well	<Null>
267	Point	317	Agriculture	273	3128	21.844369	Water Well	<Null>
9	Point	309	Agriculture	9	3128	19.580597	Water Well	<Null>
8	Point	308	Agriculture	8	3128	23.18951	Water Well	<Null>
7	Point	318	Agriculture	7	3128	22.79581	Water Well	<Null>
6	Point	318	Agriculture	6	3128	25.486091	Water Well	<Null>
319	Point	343	Home use	325	3128	21.844369	Water Well	<Null>
4	Point	298	Home use	4	3128	21.844369	Water Well	<Null>
2	Point	297	Home use	2	3128	21.05697	Water Well	<Null>
260	Point	297	Home use	266	3128	21.844369	Water Well	<Null>
316	Point	325	Home use	322	3128	20.761695	Water Well	<Null>
318	Point	331	Home use	324	3128	23.18951	Water Well	<Null>
5	Point	297	Home use	5	3128	20.433612	Water Well	<Null>
317	Point	338	Home use	323	3128	24.829925	Water Well	<Null>

Record: 15 Show: All Selected Records (0 out of 319 Selected) Options

Fig 2.0 attribute table for the wells and the boreholes.

3. ANALYSIS

3.1 Surface water analysis

Watershed delineation aids the hydrologist or water resource manager in understanding where runoff from precipitation or snowmelt will eventually drain. In the case of snowmelt, snowpack coverage may be determined from ground stations or remotely sensed observers and input into GIS to determine or predict how much water can be counted on to be available for use by cities, agriculture, and environmental habitat. A digital elevation model (DEM) from which a watershed may be delineated within ArcGIS. Another useful application for GIS regards precipitation, but other hydrologic data (evapotranspiration, infiltration, and groundwater) may be treated similarly. Precipitation is an area event measured using data from point locations. (Maidment, David R, 2002)

3.2 Ground water analysis

The two resources are by no means disjoint, as knowing where surface water recharges groundwater and where groundwater flows supply surface water is an important aspect of the hydrologic cycle. Hydrogeology is especially well suited to GIS. Groundwater moves much more slowly than surface water, on the order of less than a meter per day up to perhaps a hundred meters per day, and is 3-dimensional in flow. In contrast, surface water flows much faster and is more two-dimensional. Groundwater flow is a function of geology and “head,” the total potential energy at a location. Groundwater flows from higher head to lower head at a travel rate and flow path dictated by geology. Head values, geology, groundwater flow direction, even water table height and location of aquifers are among the quantities which may be presented spatially in GIS and used for analysis, management of water availability and water quality

3.3 Analysis tools

1n this study, ArcGIS's ArcToolbox's spatial analyst tools which contain hydrology tool sets and ArcHYDRO groundwater tools were employed. These tools allowed the transformation of the input data into useful information.
The following operations were carried out to overcome the constraints to the set criteria, leading to the step-by-step approach to effective groundwater reservoir investigation.

3.4 Analysis operation

- Watershed analysis
- Potentiometric surface generation
- Boreline creation
- Geovolume creation

3.5 Watershed analysis

Watershed is an area that drains water and other substances to a common outlet as concentrated drainage. This area is normally defined as the total area flowing to a given outlet or pour point. The boundary between two watersheds is referred to as a watershed boundary or drainage divide. An outlet, or pour point, is the point at which water flows out of an area. This is the lowest point along the boundary of the watershed. The cells in the source raster are used as pour points above which the contributing area is determined. Source cells may be features, such as dams or stream gauges, for which one may want to determine characteristics of the contributing area.

The watershed of the Asa river basin performed on digital elevation model to obtain the flow direction of Asa river basin based on the elevation data (DEM) from which the river network was extracted and the watershed delineated. This is done to know how sustainable is the water yield of the area owing to the cell value along the water course it is deduced that the cells along the water course has low values showing that along the channels there is potential of water discharge in the area. The river course in relation to watershed analysis shows that the area is on the fault zone and, and fault line serves as a medium for the hydraulic conductivity of the water into the aquifer and from the underground reservoir to the surface.

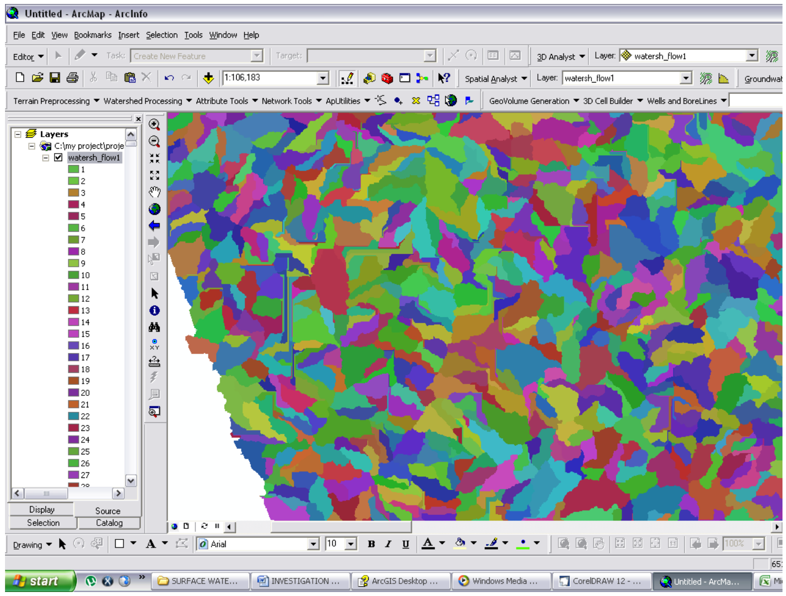


Fig 3.0: The watershed of the Asa river basin.

3.6 Potentiometric surface generation

Potentiometric surface for the aquifer was created by interpolating water levels recorded at wells and this is compared with the digital elevation model (DEM) for finding area of potential discharge. To know the point of potential discharge the Piezodepth raster generated from the well was subtracted from the raster it is noticed that it is getting shallower near the stream and increasing up the gradient.

Ground and surface water are by no means disjoint, as knowing where surface water recharges groundwater and where groundwater flows supply surface water is an important aspect of the hydrologic cycle the potentiometric surface was compared with the lineament map of the river basin and it is deduced that the area with potential discharge lies along the fault line.

The relationship between the stream network, the fault line and the Potentiometric surface of Asa river basin was shown in the map below. The potentiometric surface was compared with the lineament map and the stream network of the river basin and it is deduced that the area with potential discharge lies along the fault line.

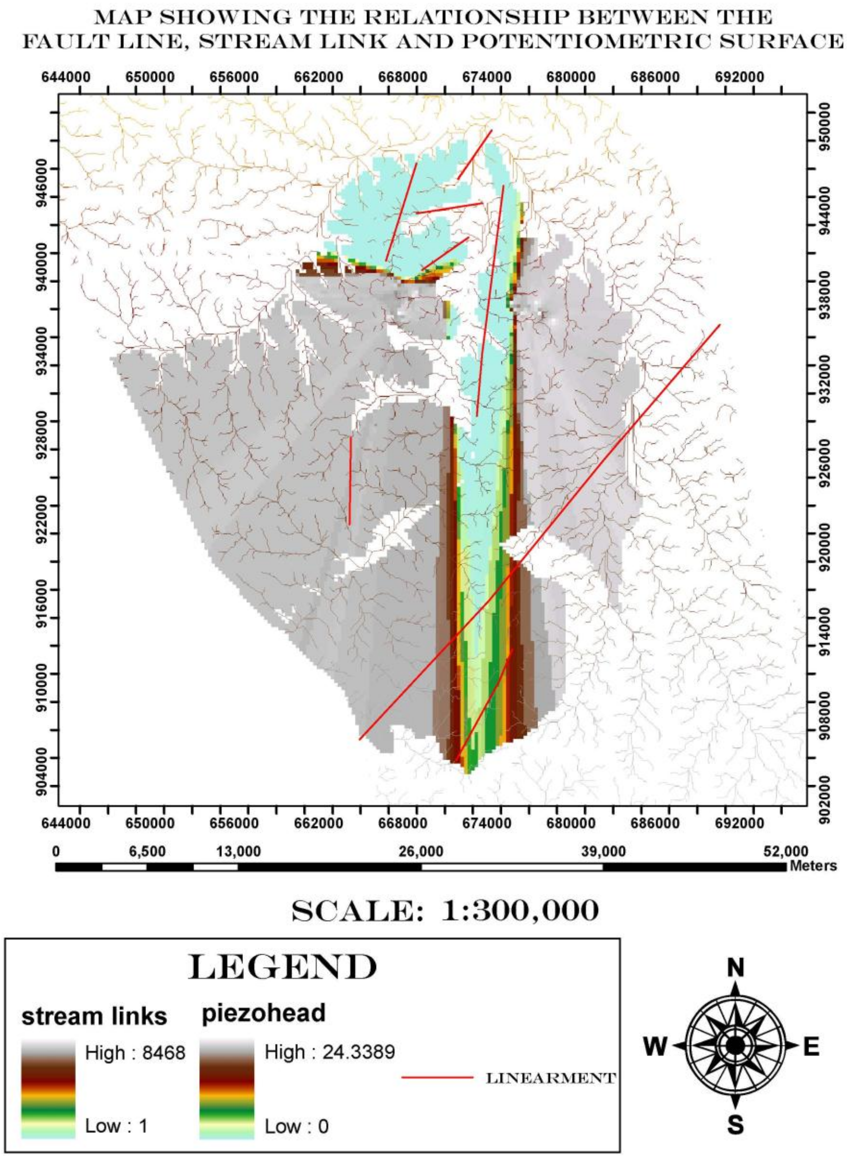


Fig 3.1: map showing the relationship between the stream network, the fault line and the Potentiometric surface of Asa river basin.

The result of the analysis performed to know the point of potential discharge was shown on the image below. Inverse distance weighted interpolation was performed, and the well layer is the input point taking the water level as the height field. The area with potential discharge is displayed in river blue color

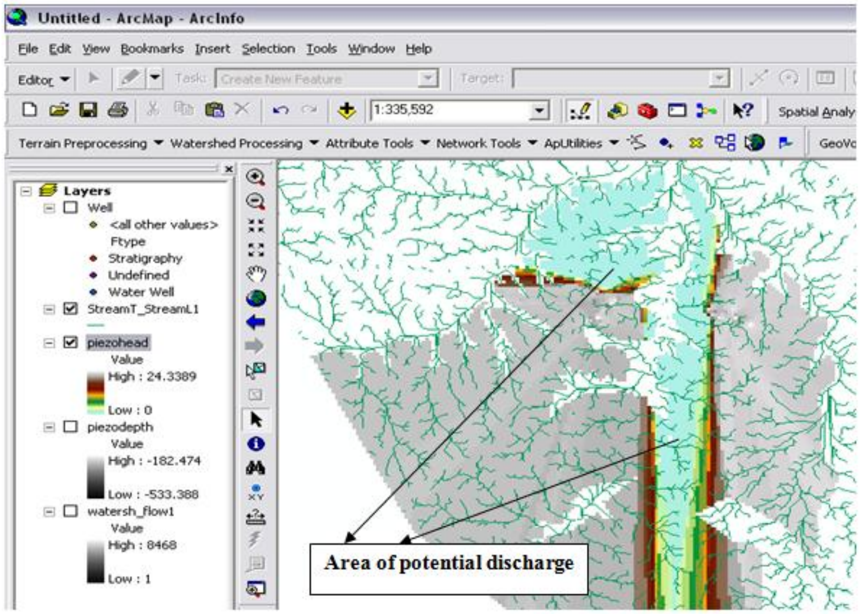


Fig 3.2: showing the area of potential discharge

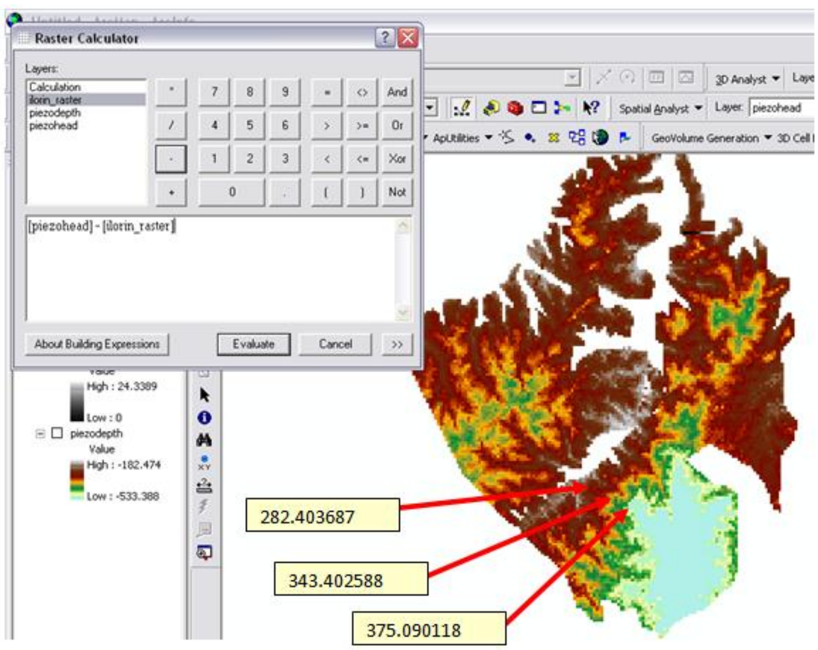


Fig 3.3: Calculating for location where Peizohead greater than DEM elevation

The image above is showing the calculation made for finding location where Peizohead is greater than DEM elevation. This was performed to know the point of potential discharge. After the Piezodepth raster generated from the well it was subtracted from the DEM and it is noticed that it is getting shallower near the stream and increasing up the gradient.

3.7 Boreline creation

Borelines are three dimensional objects that represent the hydrostatigraphy along a drilled well. The stratigraphy tables holds the top and bottom elevations observed for each hydrostatigraphy unit, displaying the vertical measurement along the strata of the boreholes in the of the study area as each of the soil layer is conformably overlain by each other.

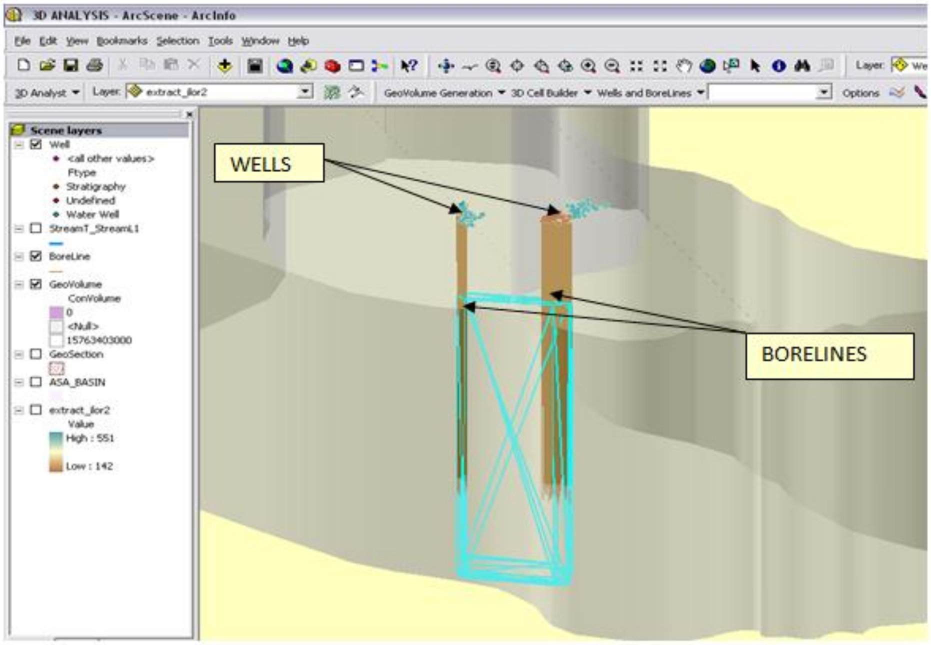


Fig 3.4: Borelines generated from boreholes log taken from the study area

Borelines generated from boreholes log taken from the study area. This is performed to show the vertical profile of the study area to know how the layers of soil conformably overlay on each other. Boreline it is a polyline Z feature (feature containing height value) describing the hydrostatigraphy of the subsurface along a segment of a drilled well.

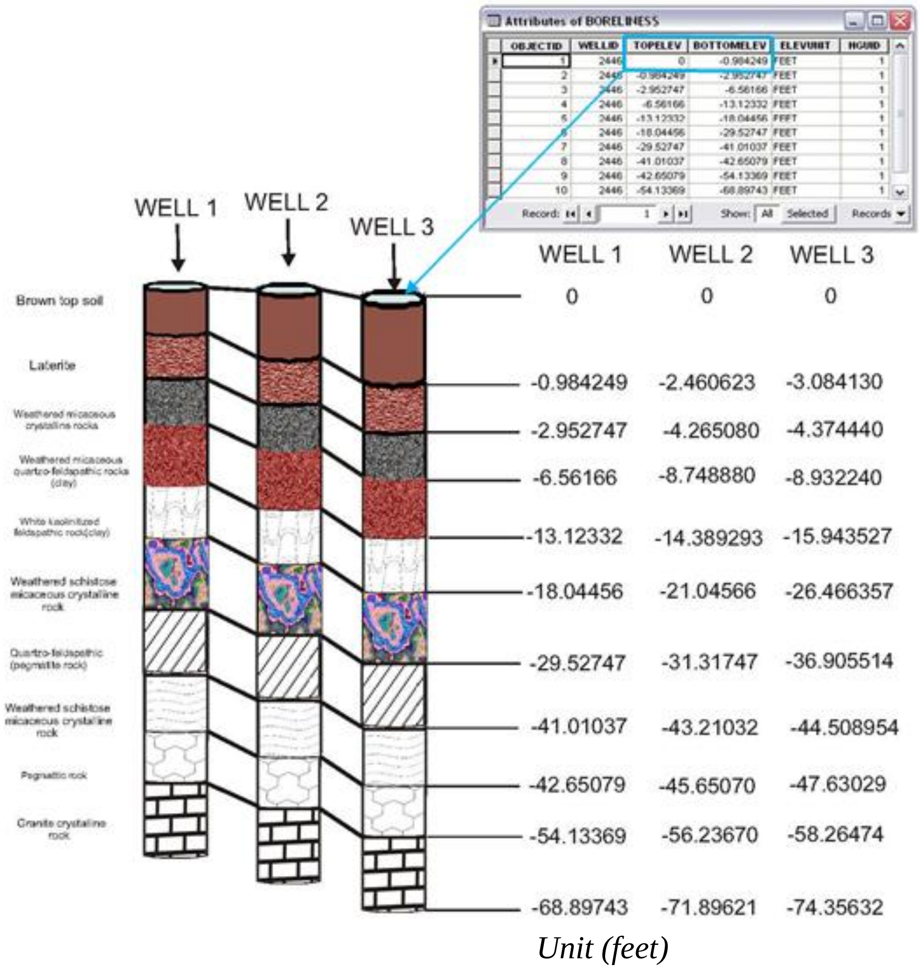


Fig 3.5: Borelines generated from boreholes log taken from the study area

3.8 Geovolume creation

Geovolume which is a multipatch layer is used in the calculation of the area and the volume of the groundwater reservoir. A multipatch is a set of three-dimensional triangles that can define the surface of a feature with volume. However, multipatches can be created by linking ArcGIS and external computational geometry programs (QHull algorithm) and attributes computed in the external programs can be written as an attribute of the multipatch.

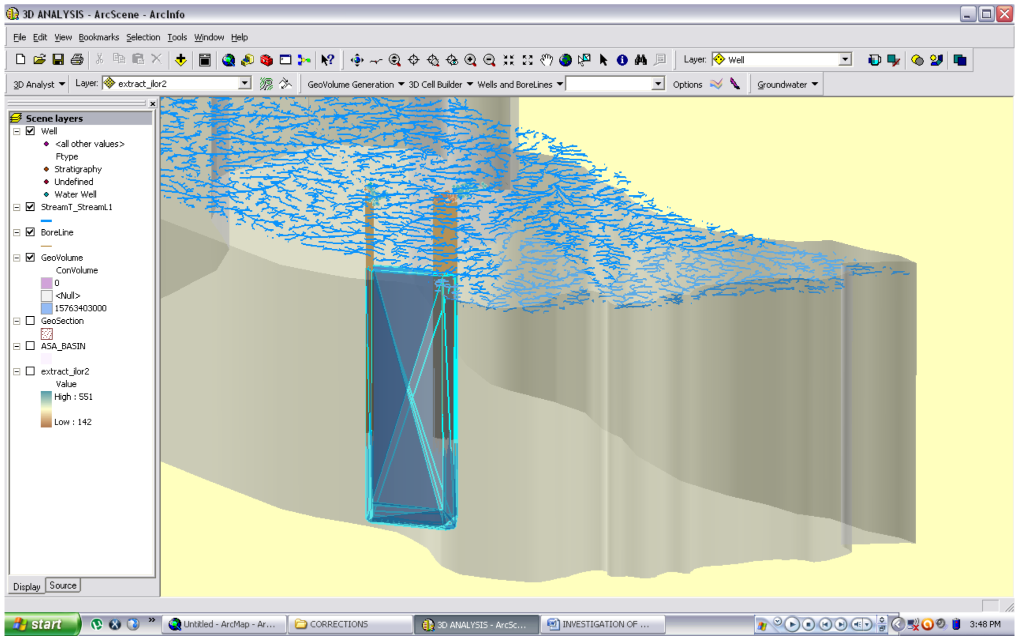


Fig 3.6: Geovolume generated from borelines.

The geovolume layer is obtained from the basin layer using the ArcHydro tools to bring the volume value obtained from the basin by interpolating this is the basis on which the calculation of the area and volume of water in the reservoir is done using the water level of the existing wells and the depth obtained from the boreholes.

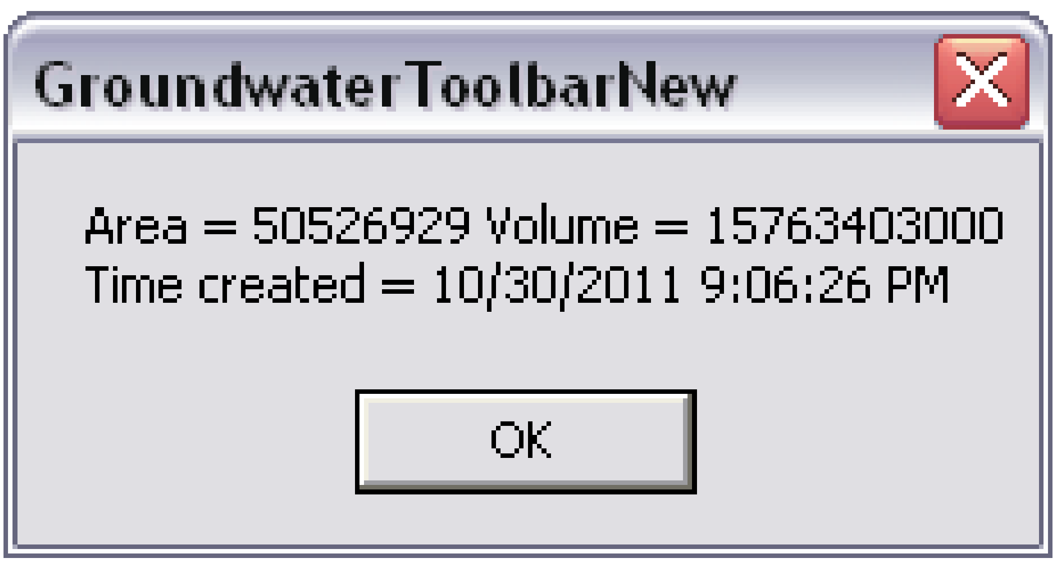


Fig 3.7: the area and the volume of the water bearing reservoir calculated.

The area and the volume of the water bearing reservoir calculated, the time and date the volume were calculated. The area the groundwater bearing reservoir is 50526929m^2 and the volume of water in the groundwater bearing reservoir is 15763403000m^2

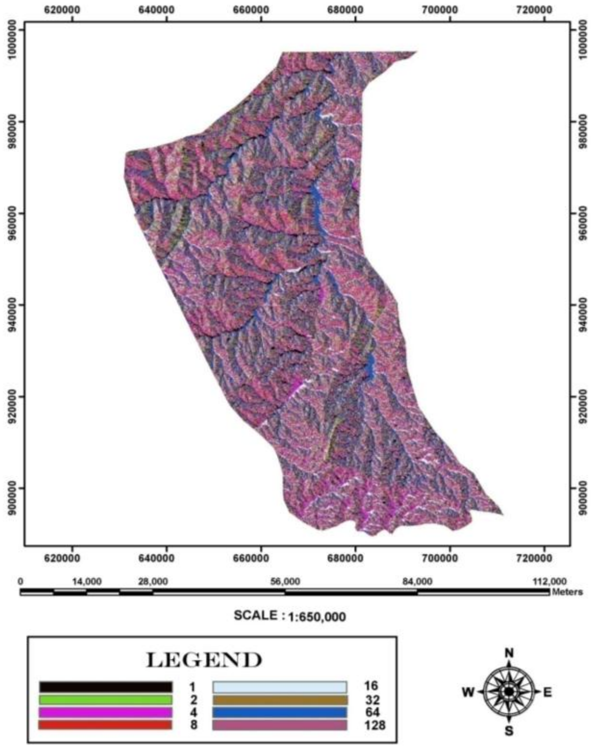


Fig 3.8: map showing the flow direction in Asa river basin

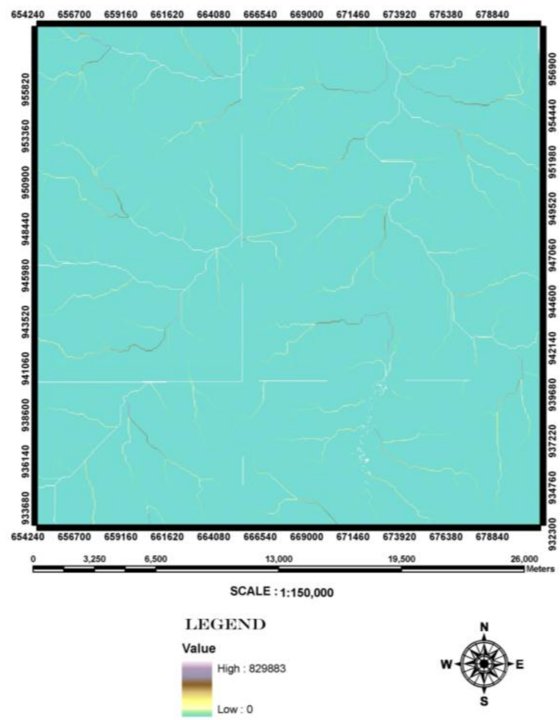


Fig 3.9: map showing the flow accumulation of Asa river basin

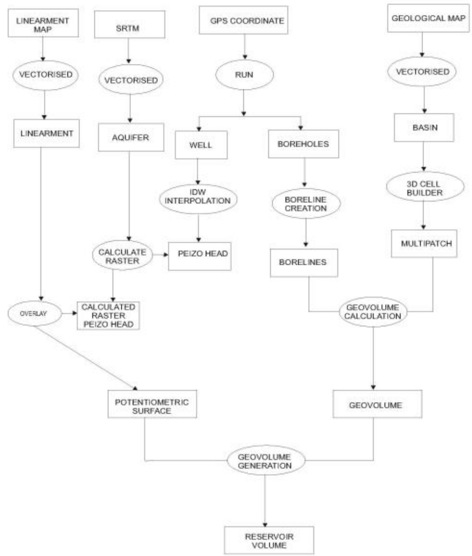
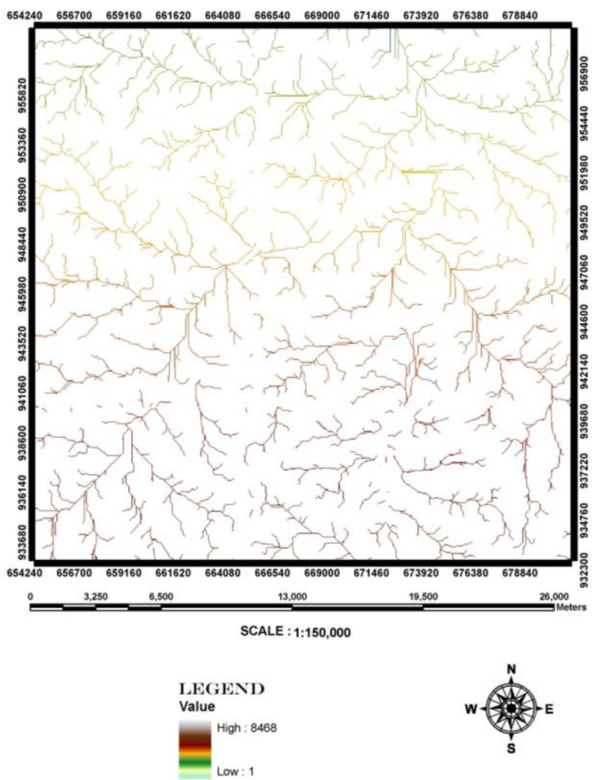


Fig 4.5: Cartographic model showing the task sequence.



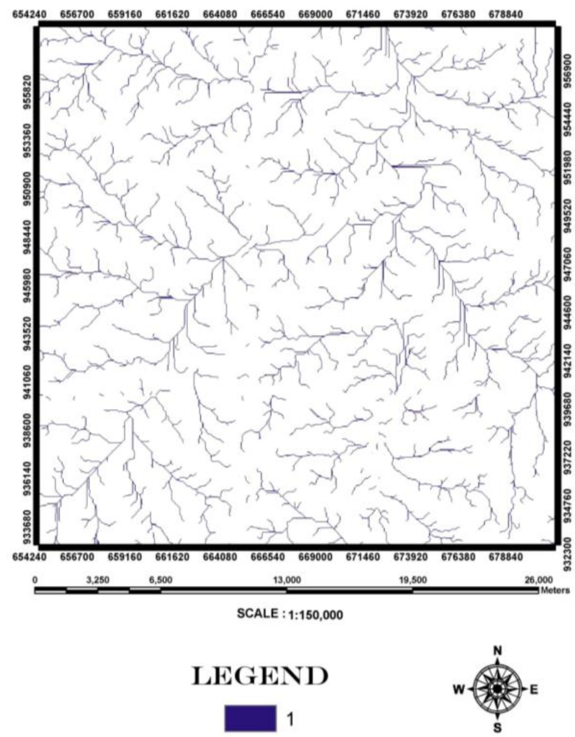


Fig 4.3: map showing the stream links of Asa river basin *Fig 4.4: map showing the stream network of Asa river basin*

4. CONCLUSION

GIS has been comprehensively applied to the process of underground reservoir investigation effectively. The results of this research work have revealed the capabilities of GIS at solving spatial problems and providing information which aid decision making. This also corroborates the fact that GIS is a veritable tool that can be applied to any discipline/endeavor for solving locational, unstructured problems and taking highly sensitive decisions.

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