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SPATIAL SCHEME FOR GROUNDWATER FLOW AND PHYSICAL PROPERTIES DISTRIBUTION IN ILARO, SOUTHWESTERN NIGERIA

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ABSTRACT

Spatial flow patterns and quality trends for groundwater in Southwestern Nigeria have been undertaken with inadequate depth of interpretation. In this study, the geographical locations of wells and respective elevation were recorded using a Global Positioning System (GPS). Well depth and water level measurements were also obtained using measuring tape. Electronic meters were employed to determine temperature, salinity, hydrogen ion concentration (pH), Total Dissolved Solids (TDS) and electrical conductivity of 109 raw water samples. Geographical Information System (GIS) softwares (Arc View 3.3 and Surfer 8) were employed in the spatial data analyses. Results show that the groundwater flows towards the Southwest and Lower Mission in the Northwest, Orita in the East and Orita-TREM in the West. The pH ranges from 6.5 to 9.5 while TDS varies between 4.81 and 483.55 mg/l. The use GIS has proved to more precise in terms of positional accuracy, than the conventional map analysis

Keywords: GIS, *spatial, groundwater, flow, quality*

1. INTRODUCTION

Groundwater has a geographical context, therefore, a study of its quality and variation over an area is important; particularly in the context of dissolved minerals present in the aquifer material that accommodates it. The geological nature of an aquifer is a pointer to the chemical composition of the groundwater in it. Water is constantly in contact with the ground in which it stagnates or circulates, until an equilibrium develops between the composition of the aquifer material and the water [1].

Evaluation of flow system and quality assessment of natural groundwater for domestic purpose is no doubt essential to human existence. Hydrologic models of water quality have been developed with a focus on groundwater chemical constituents [2]. According to There have been adequate data to support trend analysis of groundwater quality in most parts of Southwestern Nigeria, however, the compilation of all available groundwater quality data has been undertaken with inadequate depth of interpretation [3]. The Geographical Information System (GIS) method of presenting groundwater quality data for decision support does not generate problems with spatial dimension. Hence, there is a need for a knowledge base to develop oriented planning with high positional accuracy, less laborious and time-saving computer-based tool. GIS is a computer-based tool critical to water resources management studies [4–6]. The equipment used to make measurements for a GIS can be far more precise than the machines used in conventional map analysis. The versatility of GIS to elucidate spatial variation in physical parameters, which are basic to water quality assessment, has not been exploited through a serious research.

Unlike maps, GIS has the advantage of communicating information on the status of groundwater quality to concerned user communities and policy makers [7]. These researchers agree that groundwater quality parameters that are often evaluated in physical analyses include TDS, electrical conductivity, salinity and temperature. The use of GIS in groundwater quality evaluation has become increasingly recognized as the development of groundwater studies continues to expand in Nigeria. Hydrologic models are useful to evaluate the chemistry of major ions and

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hydrogeochemical processes of groundwater [8]. The GIS technique helped in mapping the water quality index (WQI) in Kaltungo area of North-Eastern Nigeria. This research established the possible linkage of the WQI with GIS geo-data base as an indispensable tool for assessing and management of groundwater [9].

Description of the movement of water in the subsurface requires knowledge of well parameters, while the physical properties of groundwater are a direct expression of the aquifer material composition. Physical parameters such as total dissolved solids (TDS), specific electrical conductance, hydrogen ion concentration (pH) and temperature are primary indicators to the characteristics of groundwater. Understanding the distribution of these properties is a key to understanding the patterns of groundwater quality. The aims of this study are to aid the use of GIS database in decision-making processes by modelling subsurface flow pattern, and to identify groundwater types through physical parameters in maps format. In this study, an advanced mapping technique is employed such that data were organized into a coherent and logical structure supported by a computing environment. The GIS, however, depicted two dimensional characteristics of the surface and ground water interaction, as well as the raster of the terrain and groundwater flow vectors in the area. The physical properties information points offered an opportunity to validate variation in groundwater quality, and check the consistency of the groundwater dataset.

2. LOCATION AND HYDROGEOLOGY

The study area is Ilaro; one of the major towns in Ogun state, South-Western part of Nigeria. As shown in Figure 1, it lies between latitudes N06^{0}52′-N06^{0}54′ and longitudes E002^{0}59′-E003^{0}01′ in the tropical region of Africa, and underlain by sedimentary rocks of the Dahomyean Miogeosynclinal Basin. The strata represented within the basin have a total thickness of about 3000m and include Alluvial Sediments, Coastal Plain Sands, Illaro Formation, Ewekoro Formation and Abeokuta Formation, which directly overlies the Basement Complex in Abeokuta [10]. The basin covers much of the continental margin of the Gulf of Guinea, and extends from the Volta Delta in Ghana in the west to the Okitipupa Ridge in Nigeria. Figure 2 shows the surface water hydrology in dendritic pattern, which reflects the morphological feature of the terrain [11]. The aquifer materials for groundwater include sandstone, Arkoses, Shale, shelly shallow water limestone, unconsolidated sands and soft marine clays. As water flows through these sedimentary rocks, it is expected that the water reacts with the mineral make up of the rocks. Physical parameters such as TDS, specific electrical conductance and pH so far developed, would provide the basic quality information on the suitability and types of groundwater in the area. A final note on this concerns temperature, which has been assumed to be a function of depth of groundwater occurrence. This is important in the case of industrial users, and also for geothermal heating and cooling.

3. METHOD OF STUDY

The varied water level conditions and unregulated shallow groundwater development in the area are common challenges, which require investigation of the aquifer systems. A reconnaissance survey was conducted to locate and identify 109 wells for the research. In the field, geographical locations of wells and ground elevation values were determined with the aid of a Global Positioning System (GPS). This was to enable the development of a digital elevation model (DEM) from a topographic data base for the GIS. Well depth and water level measurements were also obtained using measuring tape with hook, line and sinker. Electronic meters, were employed through simple procedures to determine temperature, salinity, pH, TDS and electrical conductivity of the native water samples immediately after collection. Arc View 3.3 was used to generate the 2D maps for the study area and for every measured water quality parameter, while Surfer 8 software was used to a generate the raster of groundwater flow vectors.

4. DISCUSSION OF RESULTS

4.1 Flow System

A presentation of the flow system is an important component of the surface water - groundwater interaction [12]. Figure 3 shows a two-dimensional topographic coverage from which streams in the area receive runoff and recharge the groundwater. Using maps of the study area, surface water drainage system, well locations and water table contours, the GIS produced a two dimensional map overlay that ranks the groundwater with its relative sensitivity to supply from the surface water.

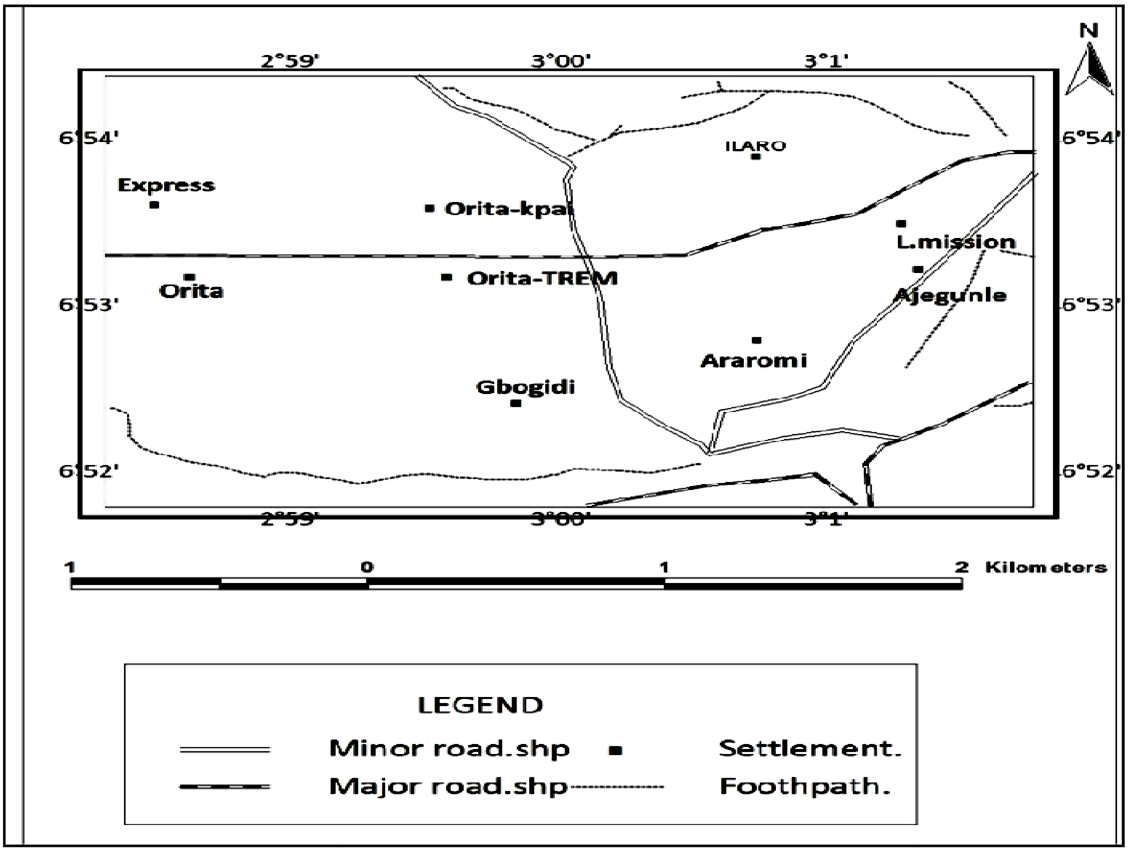

Figure:1. Map of the study area

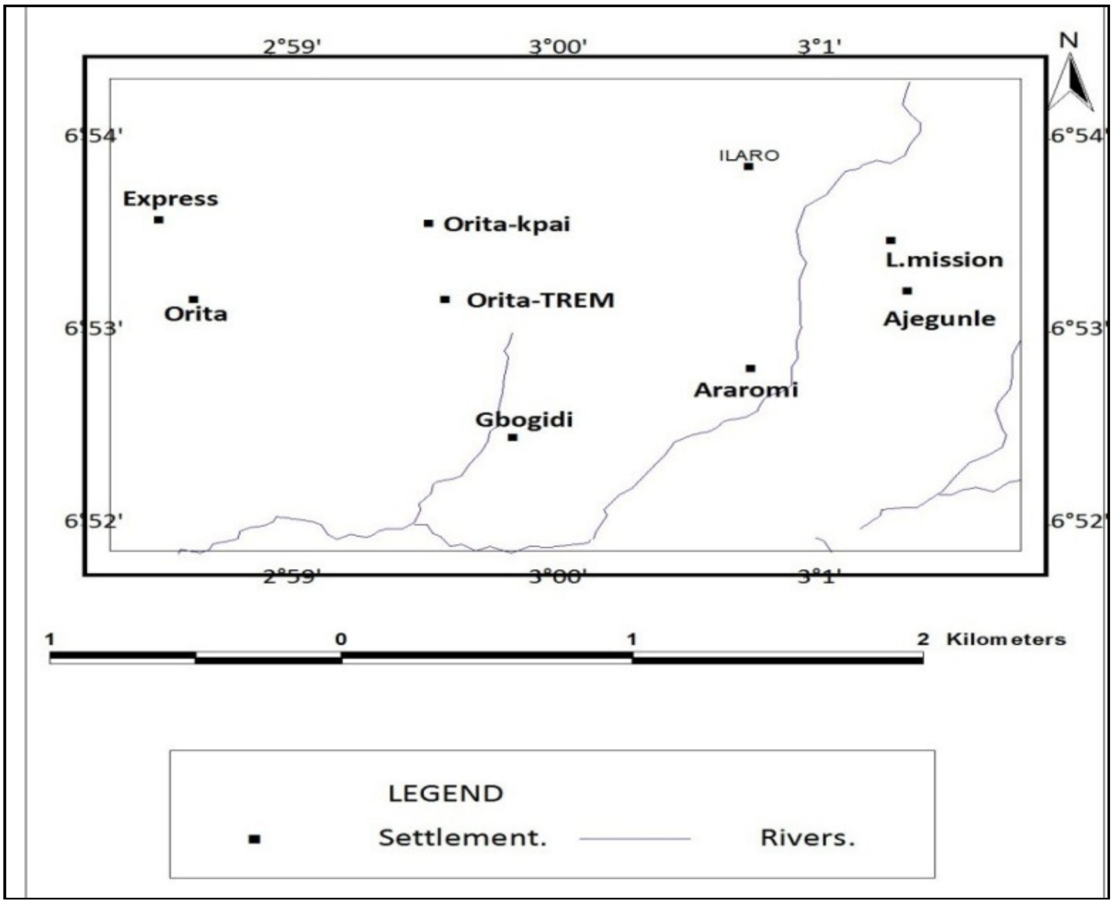

Figure:2. Map showing drainage pattern of the study area

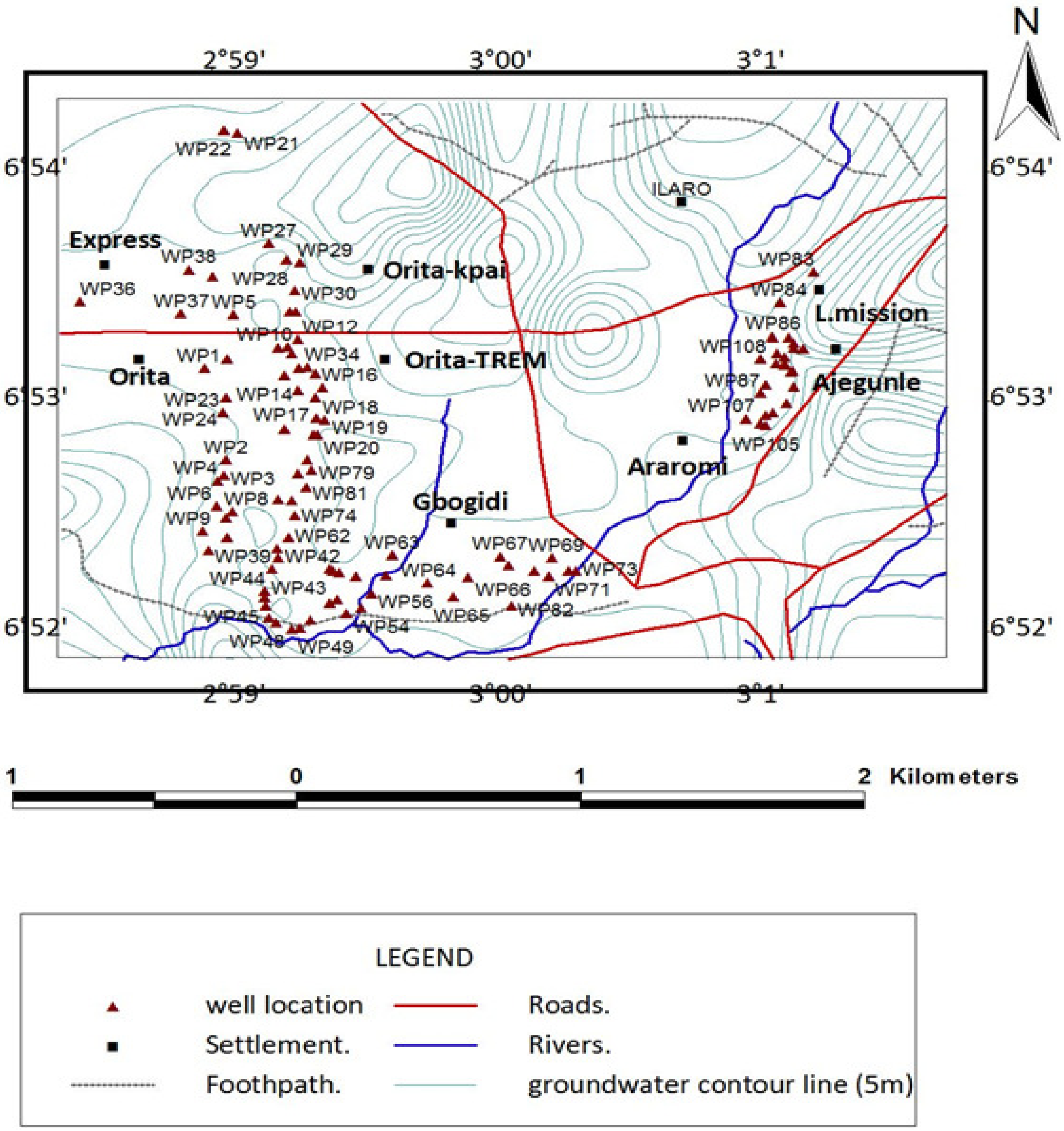

Figure:3. Map showing surface-groundwater interaction in the study area

The water table configuration is a direct expression of the groundwater flow pattern [12]. Convex contour lines in the northern and eastern parts of the study area are indicative of groundwater recharge locations. However, concave contour lines in the southwestern part of the area indicate locations of groundwater discharge into the surrounding zone. It is apparent that the drainage pattern of streams strongly controls recharge and discharge of groundwater in the area. For detailed description of topography, the digital elevation model (DEM) was used. Landform elements are best delineated using topographic attributes [13, 14]. Major topographical features recognized in the area are high lands, low lands, valleys and floodplains. The configuration of the land surface influences the expression of the subsurface. It follows that landform elements relate to hydrologic characteristics, and also influence groundwater flow. This brings about a more realistic analysis of the three-dimensional model with groundwater flow velocity and direction, as against the traditional two-dimensional static map. The subsurface drainage area shown in Figure 4, was analysed with the use of a DEM and a digital record of static water levels for well positions.

The subsurface flow system in the study area is expressed in conjunction with a three-dimensional closed system, containing the flow paths from various points at which water enters the aquifer to the topographically lower points where it leaves. The flow directions are depicted by the black arrows on the network, with the arrows pointing in the downstream directions.

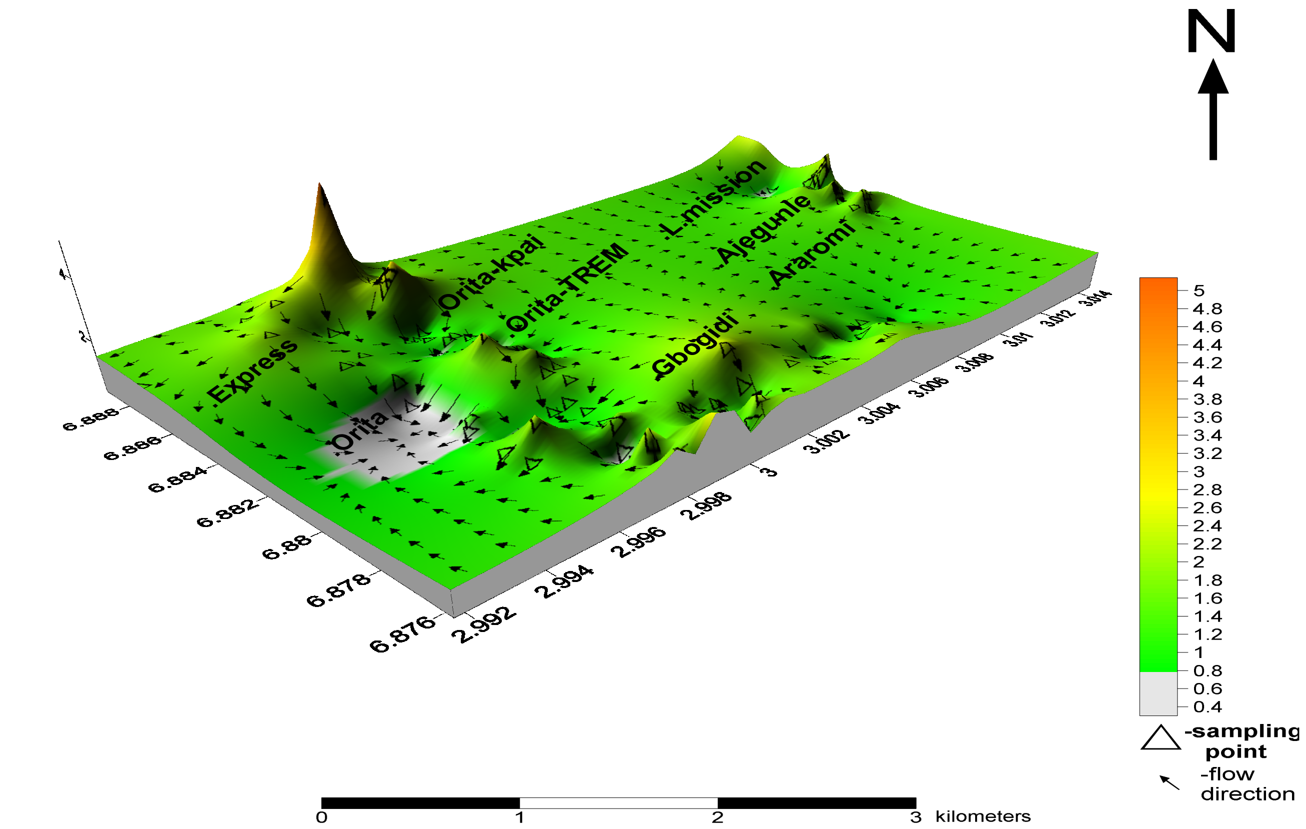

Figure:4. Terrain model and groundwater flow velocity / direction

The Darcy's law provides a valid description of the flow of groundwater in most naturally occurring hydrogeological conditions. Darcy's is a phenomenological derived constitutive equation that describes the flow of a fluid through a porous medium in relation to permeability coefficient (K) within a cross sectional area (A) [15]. At constant elevation, the instantaneous discharge rate through a porous medium (Q), the viscosity of the fluid (μ) and the pressure (P_a-P_b) drop over a given distance (L) is expressed in equation 1 below.

$$Q = -\frac{KA}{\mu}\frac{(Pa - Pb)}{L} \qquad (1)$$

Gravity is the major driving force for subsurface flow, and thus groundwater is always moving from areas of higher pressure gradient to lower pressure gradient [16]. The dataset is consistent with the raster of the groundwater flow vectors. The groundwater flow directions are complex, indicative of complicated geological conditions. The groundwater flows towards Ajegunle, Orita-kpai and Express in the Southwest, Gbogidi and Lower Mission in the Northwest, Orita in the East and Orita-TREM in the West. The groundwater flow pattern in the area was generated primarily from the distribution of heads within the hydrologic system. From figure 4, it can be observed that the distribution of heads is controlled by the relative topographic elevations; the location and effectiveness of recharge /discharge areas of the aquifer system.

5. THE WATER QUALITY PATTERN

5.1 Temperature

The temperature of groundwater is generally equal to the mean air temperature above the land surface. The temperature distribution of water from various wells in the area was numerically overlapping. Relatively high temperature waters are from wells in the eastern part, while relatively low temperature waters are from wells in the western part of the study area. The temperature of the ground water in the area ranges between 29·06^{0}C and 20.63^{0}C. The rate of increase in groundwater temperature is usually attributed to depth of its occurrence [17, 18]. Temperature is an important factor in determining allowable limits for other parameters.

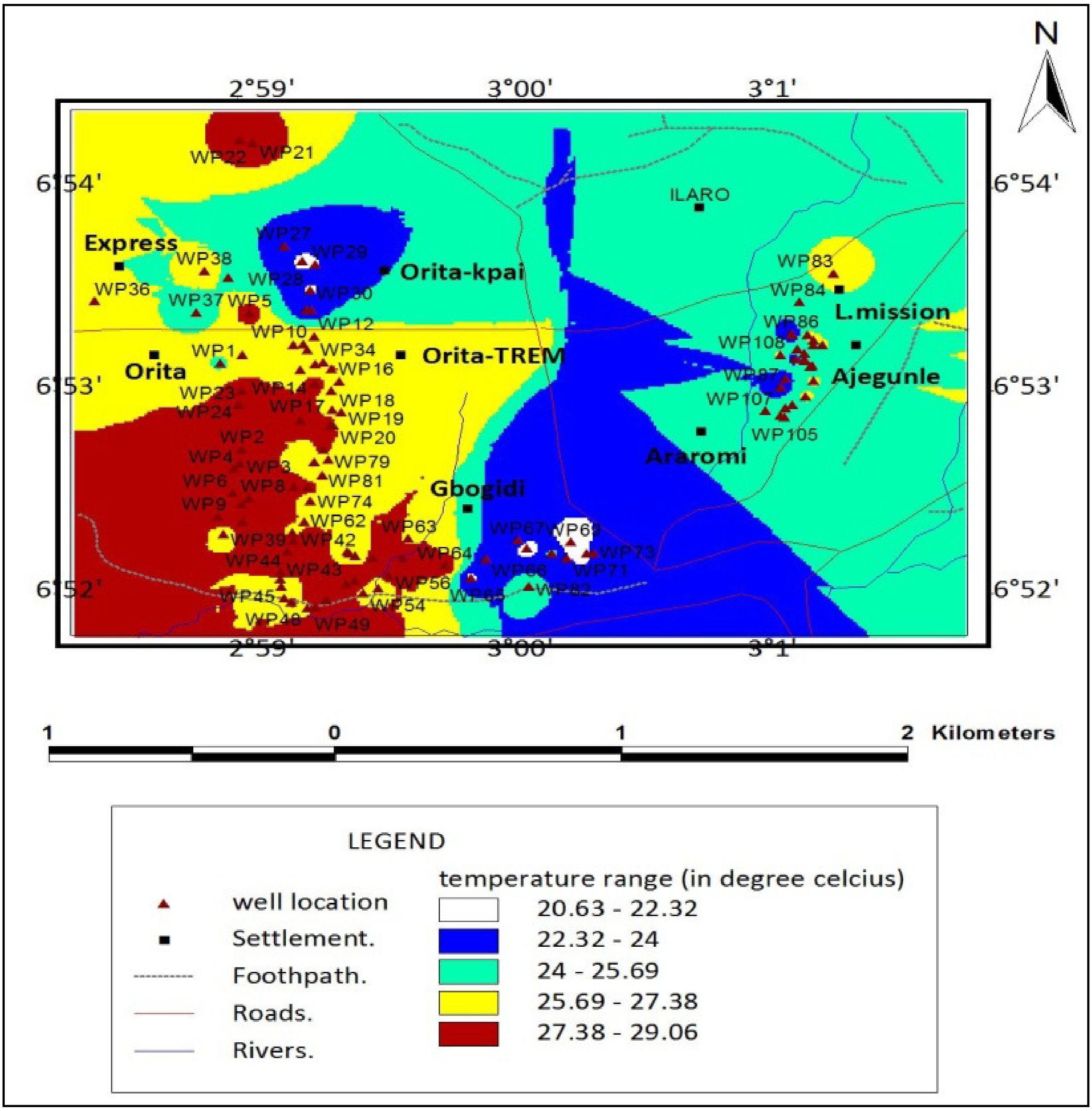

Figure:5. Spatial variation in groundwater temperature

5.2 Dissolved Salts

Salinity is a measure of the total amount of salts dissolved in groundwater. It is a valuable parameter among indicators of groundwater's suitability for various uses. Figure 4 is a map showing the generalized zones of groundwater salinity in the area. Salinity of the studied groundwater was very low. It ranged between 0 and 0.01mg/l, which is very typical of fresh water. Water having salinity less than 500mg/l is very suitable for most purposes [24]. The salinity levels in the groundwater could increase through dissolution of the aquifer materials. However, the low salinity observed would have resulted from water flowing in the laterised aquifer above the limestone. Such water flowed over the quartzitic aquifer material, which does not contribute ions into dissolved salts in the water. The reverse would have been the case if the water was flowing over limestone which dissolves easily to induce a higher salinity than water flowing over quartz.

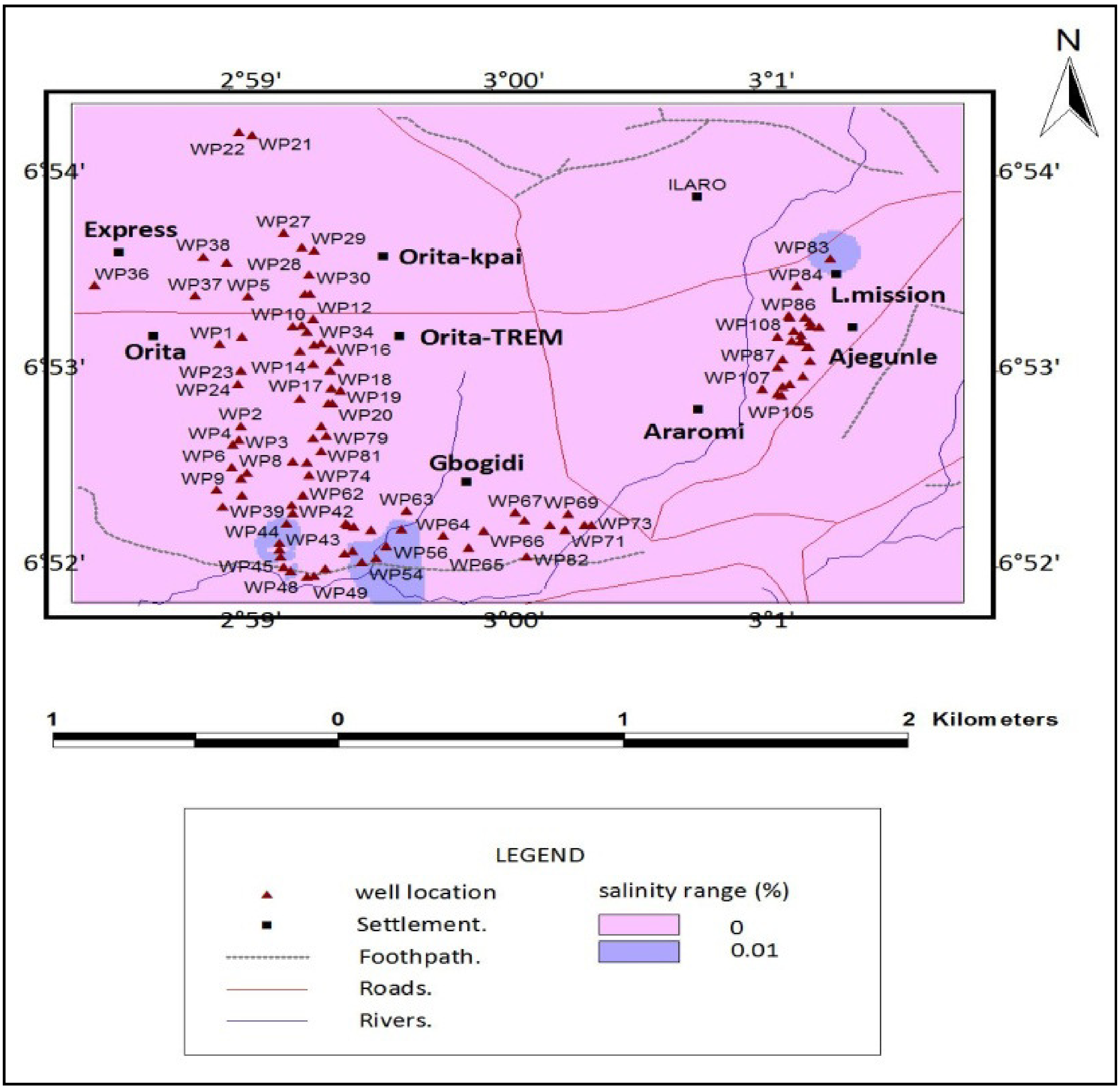

Figure:6. Spatial variation in groundwater dissolved salts

5.3 Hydrogen Ion Concentration (pH)

The concentration of hydrogen ions is measured by pH, and is equal to the -log $[H^+]$. The pH of groundwater controls which cations, anions, gases and solids dissolve into groundwater and which exit from groundwater. The pH scale ranges from 0 to 14. A pH of 7 is indicative of neutral water; if greater than 7, the water is basic; and less than 7, the water is acidic. The WHO [19] pH range standard of groundwater for permissible limit is 6.5-9.5.

In the study area the measured pH values of groundwater conforms to the limits acceptable for drinking purpose. However, three classes of pH are represented in the groundwater quality pattern of the study area. Groundwater with pH range of 6.14 – 7.18 dominates the area, especially in the western part of the study area. There was a problem of low pH, or acidic water. The occurrence of groundwater with pH range of 4.8 -6.14 in the eastern part of the study area represents contamination from anthropogenic sources from local mining activity of limestone in the area.

Considering the influences of the lower limestone and the upper lateritic aquifers in the area, the pH of the groundwater is expected to reflect the type of carbonate or silicate respectively that occurs in the solution. Predictably, in acidic solutions, H_2CO_3 is the dominant carbonate salt in the limestone aquifer, followed by HCO_3^-, then CO_3^{2-} ions as solutions become more basic. A similar progression is expected of silicates in the lateritic overburden from H_2SiO_3 to $HSiO_3^-$ to SiO_2^- as solutions change from acidic to basic. The carbonate and silicate ions serve as strong bases as strong acids are not common in natural groundwater. Consequently, as groundwater flows through the aquifers, it dissolves more carbonate than silicate minerals thereby increasing the alkalinity and the pH.

5.4 Total Dissolved Solids (TDS)

The total dissolved solids (TDS) are a good indicator of the mineralized character of groundwater. The groundwater in the study area has concentrations of various dissolved solids ranging between 4.81 and 183.55 mg/l. This is less than 500 mg/l, which is the limit indicative of suitability for domestic and industrial uses. The spatial variation map revealed that groundwater of TDS range of 4.81 – 40.56 dominated the study area. However, relatively high TDS groundwater is uncommon except in well No.63 at Lower mission area. The laterised overburden would have added dissolved constituents such as iron compounds to groundwater, as well as calcium, magnesium and bicarbonate from the limestone aquifer. These naturally-occurring constituents can affect taste and its use for various purposes. Carbonates from the limestone aquifer lead to high total dissolved solids, which are often indicative of characteristics such as hardness.

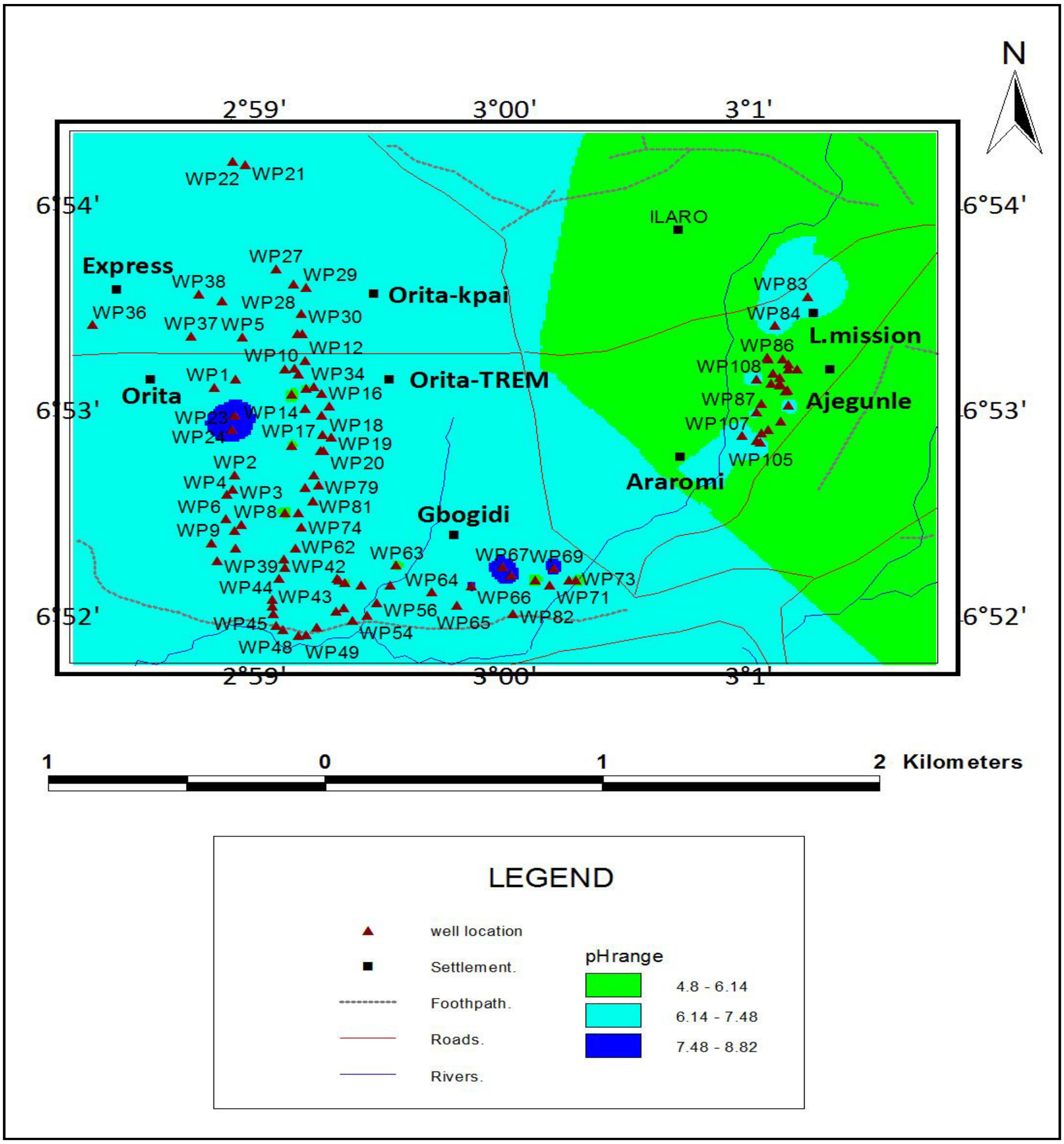

Figure:7. Spatial variation in groundwater pH

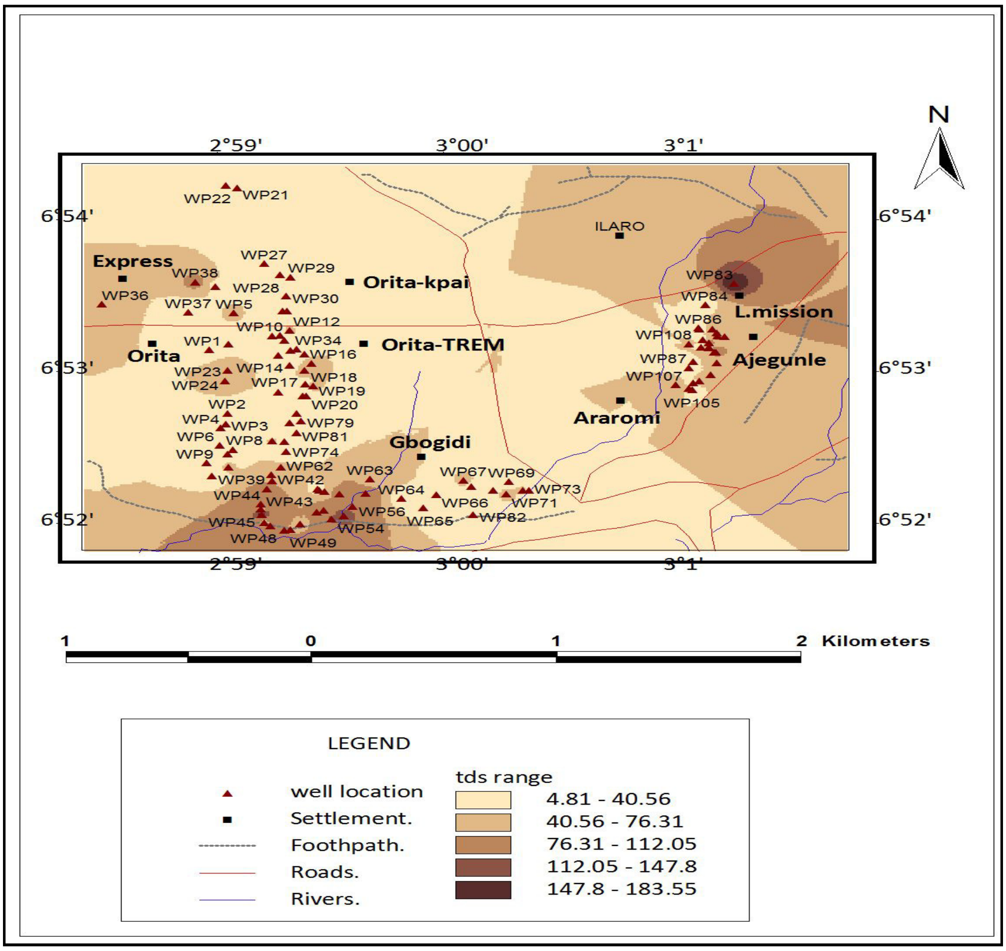

Figure:8. Spatial variation in groundwater TDS

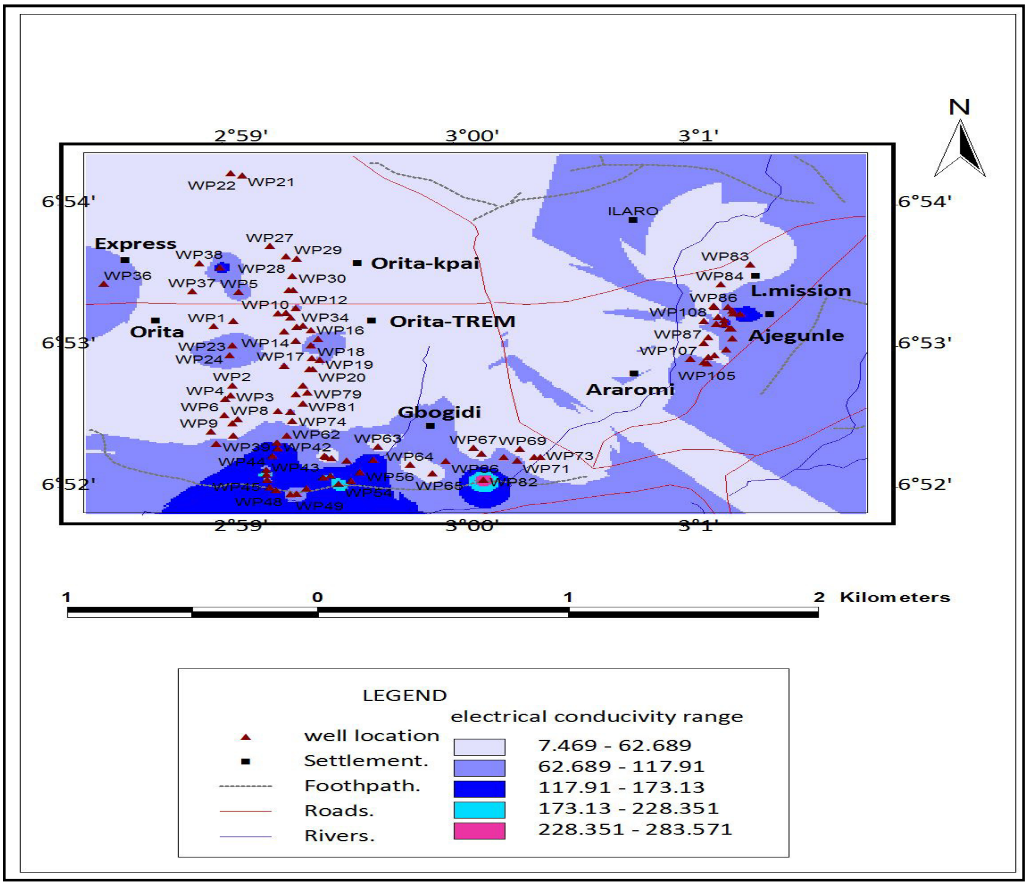

Figure:9. Spatial variation in groundwater specific electrical conductance

5.5 Electrical Conductivity

The specific electrical conductance is another important physical property useful in defining groundwater quality. This is indicative of dissolved ion concentrations in the water, which in turn reflects groundwater input, catchment geology, or diverse human impacts. Relatively low conductivity water dominates the area. One distinctive case noted in the Southern part of the study area where the electrical conductivity was high in well point (WP) 82, could be due to groundwater reacting with the minerals in the aquifer material. In the study area, five classes of conductivity were revealed as in the case of TDS. It is no doubt that the number of charged ions in groundwater increase with increase in the electrical conductivity [20]. This is true as strong positive association has been established between TDS and electrical conductivity of groundwater. The specific electrical conductance of groundwater from most of the wells in the area satisfied the 1200 µS/cm WHO [18] requirement for domestic purposes.

6. CONCLUSIONS

The Geographical Information Systems (GIS) facilitated processing of geo-referenced data to expound groundwater flow, and quality distribution based on physical properties in an area underlain by sedimentary rocks. In the utilization of GIS, information and the related landscape element are represented in the form of proper maps, which give better insight so that development and management strategies could be derived. From the output, elevations and static water level contours reveal good relationship between spot heights and groundwater flow directions depicting areas of recharge from, and discharge into the surrounding zone. Temperature, salinity, TDS and specific electrical conductance values generally fall within the acceptable limits of the World Health Organisation for domestic purposes. Further testing is not recommended, as only water with a high TDS is indicative of elevated levels of ions that could pose a health concern. These include ions such as aluminium, arsenic, copper, lead, nitrate e.t.c.
Since water is available in the subsurface and the Ilaro community uses it for sustenance, the GIS method of preparation of maps to express the records of the flow pattern with the influencing factors such as geology is the key to groundwater development oriented planning. It is apparent that geological conditions in the study area are complicated. The limestone of the Ilaro Formation which underlies the laterised overburden is bound to have contributed dissolved constituents such as calcium, magnesium and bicarbonate compounds to the groundwater. Therefore, the physical properties of water in the Ilaro aquifer system represent the net effect of the processes that have dissolved the chemical constituents. The initiative to employ a GIS approach to develop spatial information on groundwater in areas underlain by sedimentary rocks is strongly recommended.

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APPENDIX

Records of hydrogeological data form llaro

S/N	LOCATION	LATITUDE	NORTHINGS	LONGITUDE	EASTINGS	WELL DEPTH (m)	WATER LEVEL (m)	WELL HEAD (m)	CONDITION OF THE WELL	COLOUR	TEMPERATURE (°C)	PH	TDS	SALINITY (%)	ELECTRICAL CONDUCTIVITY
1	ORITA	06°53'04.9"	6.88469	002°59'44.5"	2.99569	25.95	1.45	24.5	COVERED/ 1/2CASED	COLOURLESS	25.3	6.58	20	0	30.77
2	ORITA	06°52'53.2"	6.88144	002°59'46.9"	2.99636	6	0.25	5.74	COVERED/ 1/2CASED	COLOURLESS	27.5	7.14	22	0	33.85
3	ORITA	06°52'51.2"	6.88089	002°59'46.7"	2.99631	7.5	1.34	6.16	COVERED/ 1/2CASED	COLOURLESS	27.4	7.04	38	0	58.46
4	ORITA	06°52'50.5"	6.88069	002°59'46.0"	2.99611	7.8	0.67	7.13	COVERED/ 1/2CASED	COLOURLESS	29	6.64	11	0	16.92
5	ORITA	06°52'50.1"	6.88658	002°59'47.8"	2.99661	4.22	1.22	3	COVERED/CASED	COLOURLESS	28.5	7.15	51	0	78.46
6	ORITA	06°52'47.2"	6.87978	002°59'45.9"	2.99608	6.7	1.1	5.6	COVERED/ 1/2CASED	COLOURLESS	28.5	7.22	21	0	32.31
7	ORITA	06°52'45.7"	6.87936	002°59'46.9"	2.99636	5.3	1.4	3.9	COVERED/CASED	COLOURLESS	29.1	6.97	25	0	38.46
8	ORITA	06°52'46.5"	6.87958	002°59'47.7"	2.99658	3	0.57	2.43	COVERED/CASED	COLOURLESS	27.8	6.49	14	0	21.54
9	ORITA	06°52'44.0"	6.87889	002°59'44.2"	2.99561	6.7	1.25	5.45	COVERED/ 1/2CASED	COLOURLESS	28.1	6.82	28	0	43.08
10	ORITA	06°53'07.5"	6.88542	002°59'53.9"	2.99831	20.65	0.79	19.86	COVERED/UNCASED	COLOURLESS	27.4	6.61	33	0	50.7
11	ORITA	06°53'06.7"	6.88519	002°59'54.4"	2.99844	20.15	0.93	19.22	COVERED/UNCASED	BROWNISH	26.9	6.35	43	0	66.15
12	ORITA	06°53'08.5"	6.88569	002°59'55.1"	2.99864	20.22	0.67	20.25	COVERED/UNCASED	COLOURLESS	27.2	6.21	47	0	72.31
13	ORITA	06°53'04.8"	6.88467	002°59'55.2"	2.99867	14	1.1	12.9	COVERED/UNCASED	COLOURLESS	26.15	6.08	36	0	55.38
14	ORITA	06°53'03.9"	6.88442	002°59'53.6"	2.99822	15.68	0.73	14.95	COVERED/UNCASED	COLOURLESS	26.9	6.02	31	0	47.69
15	ORITA	06°53'02.0"	6.88389	002°59'55.1"	2.99864	18.48	1.11	17.37	COVERED/UNCASED	COLOURLESS	28	6.32	4	0	6.15
16	ORITA	06°53'02.4"	6.88400	002°59'58.0"	2.99944	16.43	1.18	15.25	COVERED/UNCASED	COLOURLESS	27.2	6.24	58	0	89.23
17	ORITA	06°53'01.1"	6.88364	002°59'57.1"	2.99919	14.3	0.3	14	COVERED/1/2CASED	COLOURLESS	27.1	6.32	72	0	128.57
18	ORITA	06°52'58.5"	6.88292	002°59'57.2"	2.99922	13.4	1.37	12.03	COVERED/ 1/2CASED	COLOURLESS	27	6.21	21	0	32.31
19	ORITA	06°52'58.2"	6.88283	002°59'58.2"	2.99950	13.65	1.25	12.4	COVERED/ 1/2CASED	COLOURLESS	26.7	6.2	59	0	90.77
20	ORITA	06°52'56.4"	6.88233	002°59'57.3"	2.99925	9.93	0.38	9.55	COVERED/ 1/2CASED	COLOURLESS	26.6	6.62	12	0	18.46
21	ORITA	06°53'34.8"	6.89300	002°59'48.2"	2.99672	16.5	1.54	14.96	COVERED/UNCASED	COLOURLESS	28.7	6.22	30	0	46.15
22	ORITA	06°53'35.2"	6.89311	002°59'46.7"	2.99631	17.03	1.73	15.3	COVERED/UNCASED	COLOURLESS	27.8	6.15	24	0	36.92
23	ORITA	06°53'01.1"	6.88364	002°59'46.9"	2.99636	17.9	1.2	6.7	COVERED/UNCASED	COLOURLESS	28.2	8.83	73	0	112.31
24	ORITA	06°52'59.2"	6.88311	002°59'46.6"	2.99628	5.81	0.26	5.45	COVERED/UNCASED	COLOURLESS	27.8	7.59	61	0	93.5
25	ORITA	06°53'07.4"	6.88539	002°59'52.8"	2.99800	19.94	1.1	18.84	UNCOVERED/ 1/2CASED	COLOURLESS	27.5	6.39	31	0	47.69
26	ORITA	06°52'56.4"	6.88233	002°59'56.9"	2.99914	10.45	0.98	9.47	COVERED/ 1/2CASED	COLOURLESS	28.9	6.6	14	0	21.54
27	ORITA KPAI	06°53'20.8"	6.88911	002°59'51.8"	2.99772	32.63	1.71	30.92	COVERED/UNCASED	COLOURLESS	23.6	6.82	6	0	9.23
28	ORITA KPAI	06°53'18.7"	6.88853	002°59'53.8"	2.99828	32.18	5.58	26.6	COVERED/UNCASED	COLOURLESS	21.8	6.55	6	0	9.23
29	ORITA KPAI	06°53'18.3"	6.88842	002°59'55.3"	2.99869	31.9	1.8	30.1	COVERED/UNCASED	COLOURLESS	22.3	6.59	6	0	9.23
30	ORITA KPAI	06°53'14.8"	6.88744	002°59'54.7"	2.99853	23.2	1.9	21.3	COVERED/UNCASED	COLOURLESS	22.1	6.58	6	0	9.23
31	ORITA KPAI	06°53'12.1"	6.88669	002°59'54.8"	2.99856	25.92	3.42	22.5	COVERED/UNCASED	COLOURLESS	22.3	6.52	6	0	9.23
32	ORITA KPAI	06°53'12.1"	6.88669	002°59'54.2"	2.99839	26.1	2.1	24	COVERED/UNCASED	COLOURLESS	22.5	6.41	6	0	9.23
33	ORITA KPAI	06°53'04.1"	6.88447	002°59'57.1"	2.99919	18.98	0.93	18.05	UNCOVERED/UNCASED	COLOURLESS	27.5	6.41	28	0	43.08
34	ORITA TREM	06°53'05.0"	6.88472	002°59'56.1"	2.99892	19.18	1.18	18	COVERED/UNCASED	COLOURLESS	27.4	6.33	11	0	16.92
35	EXPRESS	06°53'06.0"	6.88500	002°59'47.0"	2.99639	23.85	1.35	22.5	COVERED/UNCASED	COLOURLESS	27	6.98	24	0	36.92
36	EXPRESS	06°53'13.3"	6.88703	003°00'30.3"	2.99175	3.68	1.42	2.26	COVERED/CASED	COLOURLESS	26.1	6.63	62	0	95.38
37	EXPRESS	06°53'11.8"	6.88661	002°59'41.8"	2.99494	34.21	2.09	32.12	COVERED/UNCASED	COLOURLESS	24.4	6.67	6	0	9.23
38	EXPRESS	06°53'16.5"	6.88817	002°59'45.4"	2.99519	33.35	1.67	31.69	COVERED/UNCASED	COLOURLESS	26.8	6.52	96	0	147.69
39	EXPRESS	06°53'17.4"	6.87822	002°59'42.7"	2.99581	33	1.15	31.85	COVERED/UNCASED	COLOURLESS	26.3	6.74	6	0	9.23
40	GBOGIDI	06°52'41.6"	6.87869	002°59'44.9"	2.99639	5.45	2.25	3.2	COVERED/CASED	COLOURLESS	28.9	7.1	49	0	75.38
41	GBOGIDI	06°52'43.3"	6.87828	002°59'47.0"	2.99797	3.07	1.17	1.9	COVERED/CASED	COLOURLESS	26.8	7.23	39	0	60
42	GBOGIDI	06°52'41.8"	6.87797	002°59'52.7"	2.99800	4.61	2.13	2.48	COVERED/CASED	COLOURLESS	29	5.98	73	0	112.31

S/N	LOCATION	LATITUDE	NORTHINGS	LONGITUDE	EASTINGS	WELL DEPTH (m)	WATER LEVEL (m)	WELL HEAD (m)	CONDITION OF THE WELL	COLOUR	TEMPERATURE (°C)	PH	TDS	SALINITY (%)	ELECTRICAL CONDUCTIVITY
43	GBOGIDI	06°52'40.9"	6.87756	002°59'52.8"	2.99781	2.6	0.55	2.05	COVERED/UNCASED	WHITISH	28	6.82	109	0.01	167.69
44	GBOGIDI	06°52'39.2"	6.87678	002°59'52.1"	2.99758	2.52	0.94	1.58	UNCOVERED/UNCASED	WHITISH	28	7.04	111	0.01	170.77
45	GBOGIDI	06°52'36.4"	6.87653	002°59'51.3"	2.99758	4.15	2.51	1.64	COVERED/CASED	COLOURLESS	27.4	6.42	49	0	75.38
46	GBOGIDI	06°52'35.5"	6.87625	002°59'51.3"	2.99761	1.54	1.04	0.5	COVERED/CASED	COLOURLESS	26	7.23	185	0.01	284.62
47	GBOGIDI	06°52'34.5"	6.87583	002°59'51.4"	2.99772	3.32	2.18	1.14	COVERED/CASED	COLOURLESS	27.1	6.23	50	0	76.92
48	GBOGIDI	06°52'33.0"	6.87567	002°59'51.8"	2.99794	2.95	1.51	1.44	UNCOVERED/CASED	COLOURLESS	27.5	6.8	104	0.01	160
49	GBOGIDI	06°52'32.4"	6.87544	002°59'52.6"	2.99844	2.67	1.12	1.55	UNCOVERED/CASED	GREYISH	26.7	7.53	82	0	126.15
50	GBOGIDI	06°52'31.6"	6.87547	002°59'54.4"	2.99869	3.45	1.95	1.5	UNCOVERED/CASED	BROWNISH	28.7	6.89	71	0	109.23
51	GBOGIDI	06°52'31.7"	6.87575	002°59'55.3"	2.99902	4.4	3.2	1.2	UNCOVERED/CASED	BROWNISH	28.2	7.01	62	0	95.38
52	GBOGIDI	06°52'32.7"	6.87636	002°59'56.5"	2.99964	2.85	0.95	1.9	COVERED/CASED	COLOURLESS	28	6.38	76	0	116.92
53	GBOGIDI	06°52'34.9"	6.87647	002°59'58.7"	2.99989	2.61	1.01	1.6	UNCOVERED/CASED	COLOURLESS	28.9	6.34	115	0.01	176.92
54	GBOGIDI	06°52'35.3"	6.87600	002°59'59.6"	3.00019	1.74	0.8	0.94	COVERED/CASED	COLOURLESS	27	6.51	117	0.01	180
55	GBOGIDI	06°52'33.6"	6.87619	003°00'00.7"	3.00064	3.64	2.44	1.2	UNCOVERED/CASED	COLOURLESS	26.6	6.89	137	0.01	210.77
56	GBOGIDI	06°52'34.3"	6.87667	003°00'02.3"	3.00097	2.44	0.8	1.64	UNCOVERED/CASED	COLOURLESS	27.6	6.85	105	0.01	161.54
57	GBOGIDI	06°52'36.0"	6.87733	003°00'03.5"	3.00142	3.3	1.4	1.9	COVERED/CASED	COLOURLESS	28.9	6.3	111	0.01	170.77
58	GBOGIDI	06°52'38.4"	6.87731	003°00'05.1"	3.00047	4.3	1.35	2.95	COVERED/UNCASED	COLOURLESS	27.5	7.05	111	0	170.77
59	GBOGIDI	06°52'38.3"	6.87742	003°00'01.7"	2.99994	5.1	1.2	3.9	COVERED/CASED	COLOURLESS	27	5.88	73	0	112.3
60	GBOGIDI	06°52'38.7"	6.87750	002°59'59.8"	2.99975	5.55	1.8	3.75	COVERED/CASED	COLOURLESS	27	6.53	14	0	21.54
61	GBOGIDI	06°52'39.0"	6.87756	002°59'59.1"	2.99967	5.3	1.59	3.71	COVERED/CASED	COLOURLESS	27.1	6.77	17	0	26.15
62	GBOGIDI	06°52'39.2"	6.87869	002°59'58.8"	2.99833	4.22	0.97	3.25	COVERED/CASED	COLOURLESS	27.3	6.96	43	0	66.15
63	GBOGIDI	06°52'43.3"	6.87806	002°59'54.0"	3.00161	5.7	2.48	3.22	COVERED/UNCASED	COLOURLESS	27.2	6.09	41	0	63.08
64	GBOGIDI	06°52'41.0"	6.87706	003°00'05.8"	3.00275	6.15	1.81	4.34	COVERED/CASED	COLOURLESS	29	6.82	13	0	20
65	GBOGIDI	06°52'37.4"	6.87658	003°00'09.9"	3.00356	4.05	1.62	2.43	COVERED/CASED	BROWNISH	22	7.31	23	0	35.38
66	GBOGIDI	06°52'35.7"	6.87728	003°00'12.8"	3.00403	3.56	1.16	2.4	UNCOVERED/CASED	BROWNISH	23.5	7.52	23	0	35.38
67	GBOGIDI	06°52'38.2"	6.87800	003°00'14.5"	3.00503	3.09	1.85	1.24	UNCOVERED/CASED	COLOURLESS	23.5	7.6	48	0	73.85
68	GBOGIDI	06°52'40.8"	6.87769	003°00'18.1"	3.00531	3.34	1.3	2.04	COVERED/CASED	COLOURLESS	21.1	7.97	38	0	58.46
69	GBOGIDI	06°52'39.7"	6.87794	003°00'19.1"	3.00669	3.49	1.36	2.13	COVERED/CASED	COLOURLESS	20.6	8.18	24	0	36.92
70	GBOGIDI	06°52'40.6"	6.87750	003°00'24.1"	3.00611	10.1	0.6	9.5	COVERED/1/2CASED	COLOURLESS	24.5	5.35	20	0	30.77
71	GBOGIDI	06°52'39.0"	6.87731	003°00'22.0"	3.00658	4.13	1.83	2.3	COVERED/UNCASED	COLOURLESS	22.3	7.24	54	0	83.08
72	GBOGIDI	06°52'38.3"	6.87750	003°00'23.7"	3.00719	5.65	0.9	4.75	COVERED/UNCASED	COLOURLESS	20.8	7.19	49	0	75.38
73	GBOGIDI	06°52'39.0"	6.87750	003°00'25.9"	3.00742	9.12	0.82	8.3	COVERED/1/2CASED	COLOURLESS	24.3	5.52	18	0	27.69
74	GBOGIDI	06°52'39.0"	6.87947	003°00'26.7"	2.99853	10.03	0.88	9.15	COVERED/1/2CASED	COLOURLESS	26.8	6.51	20	0	30.77
75	GBOGIDI	06°52'46.1"	6.88000	002°59'54.7"	2.99844	4.2	1	3.2	COVERED/1/2CASED	COLOURLESS	27.8	6.4	38	0	58.46
76	GBOGIDI	06°52'48.0"	6.88003	002°59'54.4"	2.99800	5.22	0.88	4.34	COVERED/CASED	COLOURLESS	28.1	5.94	44	0	67.69
77	GBOGIDI	06°52'48.1"	6.88253	002°59'52.8"	2.99822	6.6	2.41	4.19	COVERED/CASED	COLOURLESS	28.3	6.1	39	0	60
78	GBOGIDI	06°52'57.1"	6.88142	002°59'53.6"	2.99892	6.75	2.1	4.65	COVERED/CASED	COLOURLESS	28	6.16	42	0	64.62
79	GBOGIDI	06°52'53.1"	6.88106	002°59'56.1"	2.99908	5.15	1.45	3.7	COVERED/1/2CASED	COLOURLESS	26	6.39	6	0	9.23
80	GBOGIDI	06°52'51.8"	6.88094	002°59'56.7"	2.99864	3.8	1.55	2.25	COVERED/CASED	COLOURLESS	25.9	6.6	6	0	9.23
81	GBOGIDI	06°52'51.4"	6.88044	002°59'55.1"	2.99889	6.2	1.5	4.7	COVERED/CASED	COLOURLESS	26.7	6.55	6	0	9.23
82	GBOGIDI	06°52'49.6"	6.87625	002°59'56.0"	3.00539	4.1	2.02	2.08	COVERED/CASED	BROWNISH	25.5	7.04	7	0	10.76

S/N	LOCATION	LATITUDE	NORTHINGS	LONGITUDE	EASTINGS	WELL DEPTH (m)	WATER LEVEL (m)	WELL HEAD (m)	CONDITION OF THE WELL	COLOUR	TEMPERATURE (^{0}C)	PH	TDS	SALINITY (%)	ELECTRICAL CONDUCTIVITY
83	GBOGIDI	06^{0}52'34.5"	6.88808	003^{0}00'19.4"	3.01494	5.15	2.65	2.5	COVERED/CASED	BROWNISH	27	6.79	184	0.01	283.08
84	LOWER MISSION	06^{0}53'17.1"	6.88700	003^{0}00'53.8"	3.01389	14.27	0.59	13.68	COVERED/CASED	COLOURLESS	24.2	6.58	9	0	13.85
85	LOWER MISSION	06^{0}53'13.2"	6.88575	003^{0}00'50.0"	3.01367	15	1	14	COVERED/UNCASED	COLOURLESS	23.3	5.11	6	0	9.23
86	LOWER MISSION	06^{0}53'08.7"	6.88581	003^{0}00'49.2"	3.01364	12.54	0.97	11.75	COVERED/UNCASED	COLOURLESS	22.4	6.25	21	0	32.31
87	LOWER MISSION	06^{0}53'08.9"	6.88378	003^{0}00'49.1"	3.01328	13.15	1.05	12.1	COVERED/UNCASED	COLOURLESS	22.3	6.3	23	0	35.38
88	LOWER MISSION	06^{0}53'01.6"	6.88408	003^{0}00'47.8"	3.01344	11.5	2.27	9.23	COVERED/UNCASED	COLOURLESS	23.2	5.63	10	0	15.38
89	LOWER MISSION	06^{0}53'02.7"	6.88522	003^{0}00'48.4"	3.01381	10.09	1.5	8.59	COVERED/UNCASED	COLOURLESS	23.7	6.35	6	0	9.23
90	AJEGUNLE	06^{0}53'06.8"	6.88483	003^{0}00'49.7"	3.01375	8.92	0.71	8.21	COVERED/UNCASED	COLOURLESS	22.3	4.75	10	0	15.38
91	AJEGUNLE	06^{0}53'05.4"	6.88483	003^{0}00'49.5"	3.01403	8.99	0.99	8	COVERED/UNCASED	COLOURLESS	22.9	5.06	60	0	92.3
92	AJEGUNLE	06^{0}53'05.5"	6.88478	003^{0}00'50.5"	3.01403	7.8	0.9	6.9	COVERED/UNCASED	COLOURLESS	26.6	4.89	91	0	140
93	AJEGUNLE	06^{0}53'05.2"	6.88506	003^{0}00'50.5"	3.01403	6.9	0.8	6.1	COVERED/UNCASED	COLOURLESS	25.9	4.96	98	0	150.77
94	AJEGUNLE	06^{0}53'06.2"	6.88556	003^{0}00'50.5"	3.01431	8.3	1.45	6.85	COVERED/1/2CASED	COLOURLESS	26.6	5.07	82	0	126.15
95	ARAROMI	06^{0}53'08.0"	6.88539	003^{0}00'51.5"	3.01433	7.7	0.6	7.1	COVERED/UNCASED	COLOURLESS	25.3	5.23	91	0	140
96	ARAROMI	06^{0}53'07.4"	6.88575	003^{0}00'51.6"	3.01414	7.65	1.3	6.35	COVERED/1/2CASED	COLOURLESS	26.3	6.13	60	0	92.3
97	ARAROMI	06^{0}53'08.7"	6.83350	003^{0}00'50.9"	3.01456	5.91	2.68	3.23	UNCOVERED/UNCASED	BROWNISH	24.5	4.74	58	0	89.23
98	ARAROMI	06^{0}53'06.0"	6.88536	003^{0}00'52.4"	3.01461	7.93	2.73	5.2	COVERED/UNCASED	COLOURLESS	25.9	6.18	63	0	96.92
99	ARAROMI	06^{0}53'07.3"	6.88458	003^{0}00'52.6"	3.01428	9.12	0.79	8.33	COVERED/UNCASED	COLOURLESS	25	5.06	111	0	170.77
100	ARAROMI	06^{0}53'04.5"	6.88456	003^{0}00'51.4"	3.01422	10.25	1.94	8.31	COVERED/CASED	COLOURLESS	26.3	6.81	63	0	96.92
101	ARAROMI	06^{0}53'04.4"	6.88403	003^{0}00'51.2"	3.01431	12.32	1.27	11.05	COVERED/UNCASED	COLOURLESS	26.1	6.8	60	0	92.3
102	ARAROMI	06^{0}53'02.0"	6.88342	003^{0}00'51.5"	3.01408	9.95	1.75	8.2	COVERED/CASED	COLOURLESS	26.2	5.98	42	0	64.62
103	ARAROMI	06^{0}53'00.3"	6.88311	003^{0}00'50.7"	3.01367	13.72	1.97	11.75	UNCOVERED/CASED	COLOURLESS	25.4	5.06	59	0	90.77
104	ARAROMI	06^{0}52'59.2"	6.88300	003^{0}00'49.2"	3.01344	19.23	2.18	17.05	COVERED/CASED	BROWNISH	24.3	6.21	20	0	30.77
105	ARAROMI	06^{0}52'58.8"	6.88264	003^{0}00'48.4"	3.01342	20.01	1.25	18.76	COVERED/UNCASED	BROWNISH	24	6.3	22	0	33.85
106	ARAROMI	06^{0}52'57.5"	6.88272	003^{0}00'48.3"	3.01328	18.75	1.72	17.03	COVERED/UNCASED	BROWNISH	24.5	6.32	52	0	80
107	ARAROMI	06^{0}52'57.8"	6.88289	003^{0}00'47.8"	3.01281	19.82	1.67	18.15	COVERED/CASED	BROWNISH	24.2	6.4	63	0	96.92
108	ARAROMI	06^{0}52'58.4"	6.88500	003^{0}00'46.1"	3.01328	17.25	1.99	15.26	COVERED/UNCASED	COLOURLESS	26.2	7.08	45	0	69.23
109	ARAROMI	06^{0}53'06.0"	6.88792	003^{0}00'47.8"	2.99594	25.2	2.2	23	COVERED/CASED	COLOURLESS	25.5	6.57	32	0	49.23