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Hydrological Characteristics of Groundwater in the East Baghdad Oil Field (Rashidiya and the Southern Region Using GIS).

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Abstract

After knowing the natural phenomena, we will study in this chapter the characteristics of groundwater through spatial analysis of wells and their geographical distribution, renewing the depths of wells, the direction and movement of groundwater, well recharge, determining their fixed and variable levels, and chemical and physical characteristics.The study was based on a sample of (40) wells distributed in a different way in the region. The spatial analysis of groundwater is done by estimating and measuring the value of groundwater, which has a fundamental role in water management, as it gives a clear idea about the volume of groundwater, its production capacity, its level, and the number of wells and their depths in the region.

Keywords: *Hydrology, Groundwater, Wells, Water System, Water Basins, Rashidiya.*

Introduction

Natural resources play a major role in reviving the economy in any country. Water is at the forefront of these resources, which is the basic element in building human civilizations, in addition to its control over other natural resources. Groundwater, which is the first alternative when surface water is not available, is important in social and economic life. Therefore, it has become necessary to expand studies in this field to discover groundwater and extract it to benefit from various investments.

Knowing the origin and composition of oil and its relationship to groundwater in the region is one of the important matters that economically control the establishment of any related projects. To reach accurate and rapid results, we have relied on geographical techniques of remote sensing and geographic information systems for the purpose of studying the distribution of water wells, analyzing the samples that were collected, drawing different maps, and counting the models specific to the study, leading to a logical analysis of the region regarding the spatial analysis of groundwater and its polluting environmental effects.

The study problem revolves around asking the following question: What are the hydrological characteristics of groundwater and does oil influence the characteristics of the groundwater reservoir?

The study hypothesis is summarized in the diversity of hydrological properties of groundwater and the varying effect of oil on the quality of this water in the study area.

To study any region, its astronomical (coordinate) location and its geographical location must be determined as follows:

Astronomical Location (Coordinates)

It is the location defined by longitude and latitude lines, as the study area, represented by the East Baghdad Oil Field, is located between longitudes (0 20 44) and (0 0 45) east and latitudes (0 0 33) and (0 35 33) north.

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Geographical Location of the Region

The East Baghdad oil field is one of the fields located in central Iraq, located (10) km2 to the east of Baghdad Governorate and extends in a northwest-southeast direction from the Taji area northwest of Baghdad to the north of the Suwaira area, with a length of approximately (120) km2 and a width ranging from (10) to (20) km2 approximately. As shown in Map No. (1), it includes within its borders two fields (the southern region - Al-Rashidiya), and the total area of the region includes (120) km2. As shown in Map No. (1).

The research focuses on the groundwater system, its changes in its level, chemical composition, temperature, flow, and other factors affecting the system. Naturally, it is related to feeding from surface runoff and rainfall, and industrially, it is related to human activity, such as crafts, grazing, and raising the water level in water basins (Bilan, Hussein, 2008, p. 15). The numerical distribution of wells in the central region (Al-Rashidiya) is uneven and depends on their feeding from the Tigris River. As for the water wells in the southern region, they are distributed in the region west and northwest of the region, which derives its feeding from the Diyala River and its branching streams. As for the region east and south of the region, there wells are few because the wells in this region are salty. Also, this part of the study area contains sanitary landfill areas that negatively affect the groundwater. By reviewing the relevant authorities represented by the Ministry of Water Resources and the General Authority for Groundwater in Baghdad

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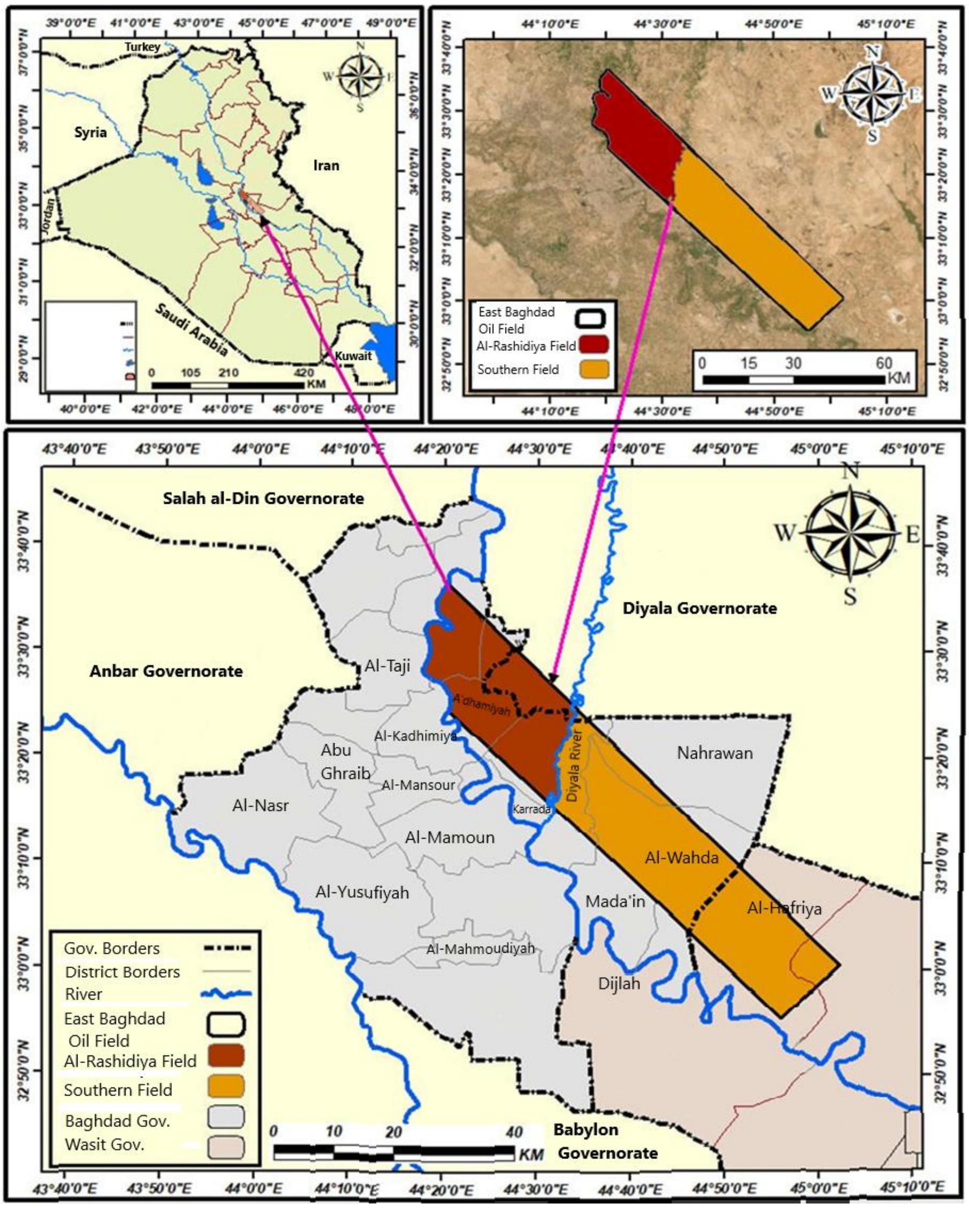
Map No. (1). Geographic Location of the Study Area.



Source: Researcher based on the Ministry of Oil, East Baghdad Oil Field, Geology Department, 1:5000 for the year 2024, using Arc GIS 10.8.

Groundwater (Wells)

Numerical Distribution of Wells

The field study distributed the wells at a rate of (40) wells, as I was provided with (27) samples from the Ministry of Water, the Groundwater Resources Authority, and also three wells from the Ministry of Oil/East Baghdad Oil Field, as shown in Figure No. (1), and ten wells were analyzed for groundwater by the researcher as shown in Figure No. (2-2) in Table (1) and Map No. (2(.

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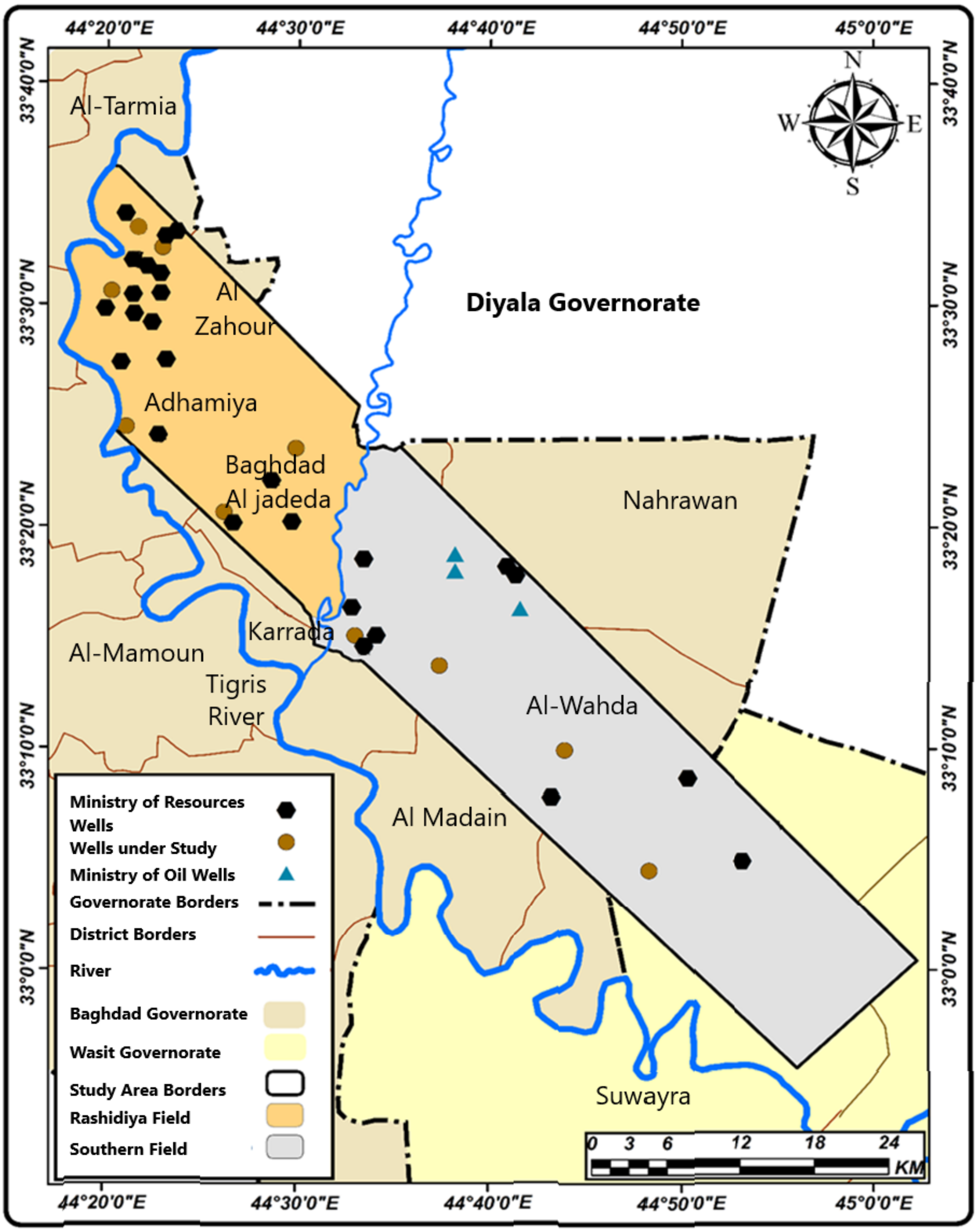
Map No. (2). Geographical Distribution of Wells in the Study Area



Source: The researcher based on data from Table (1) and Arc GIS10.8, Density program

Groundwater Movement and Direction

Groundwater generally moves from levels of high hydraulic pressure towards levels of lower pressure after the water enters the unsaturated ventilation zone confined between the ground surface and the saturation level. This movement is slow compared to the movement of surface water (Jaber, Hadi Khadir Saleh, 2002, pp. 13-14). Its speed is about (0.00002) km/hour, and the movement of groundwater is affected by multiple variables, including the geological structure, such as folds, faults, joints, and the general slope of the rock layers containing water.

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Groundwater is controlled by many determinants, including the speed of groundwater movement. The speed of groundwater movement is related to the cross-section, hydraulic gradient, and permeation rate. Water flow is often laminar in the porous medium, meaning that the fluid particles are in the form of lines that overlap each other and are parallel, or in the form of turbulent flow in which the water particles are irregular and overlapping, and their speed is high and their directions change with time, although the average speed does not change with time (Hanun, Jalil Jassim Muhammad, 2010, p. 36).

The forms of groundwater movement according to Map (2) and Table (1) are divided into:

Vertical downward movement: It represents the movement of water penetration into cracks and valley bottoms and floods through which the groundwater reservoirs within the region are fed (Al-Ibrahimi, Suhaila, 2012).

Vertical upward movement: The process of water seepage from the deeper layer to the shallower layer represents the effect of piezometric pressure until groundwater seeps and these are found in drainage areas.

Horizontal movement (lateral movement): It is considered more important than the vertical movement due to its effect on the spatial variation in the quality and quantity of groundwater from one area to another and is represented by the movement from the feeding area towards the drainage area. It is clear from the groundwater movement map that the groundwater in the study area moves in different directions. There is a movement of water towards the northwest and there is another movement towards the northeast, but the general direction of groundwater movement in the study area is from the northeast towards the southwest (Al-Fatlawi, A. N., 2011, p. 210.).

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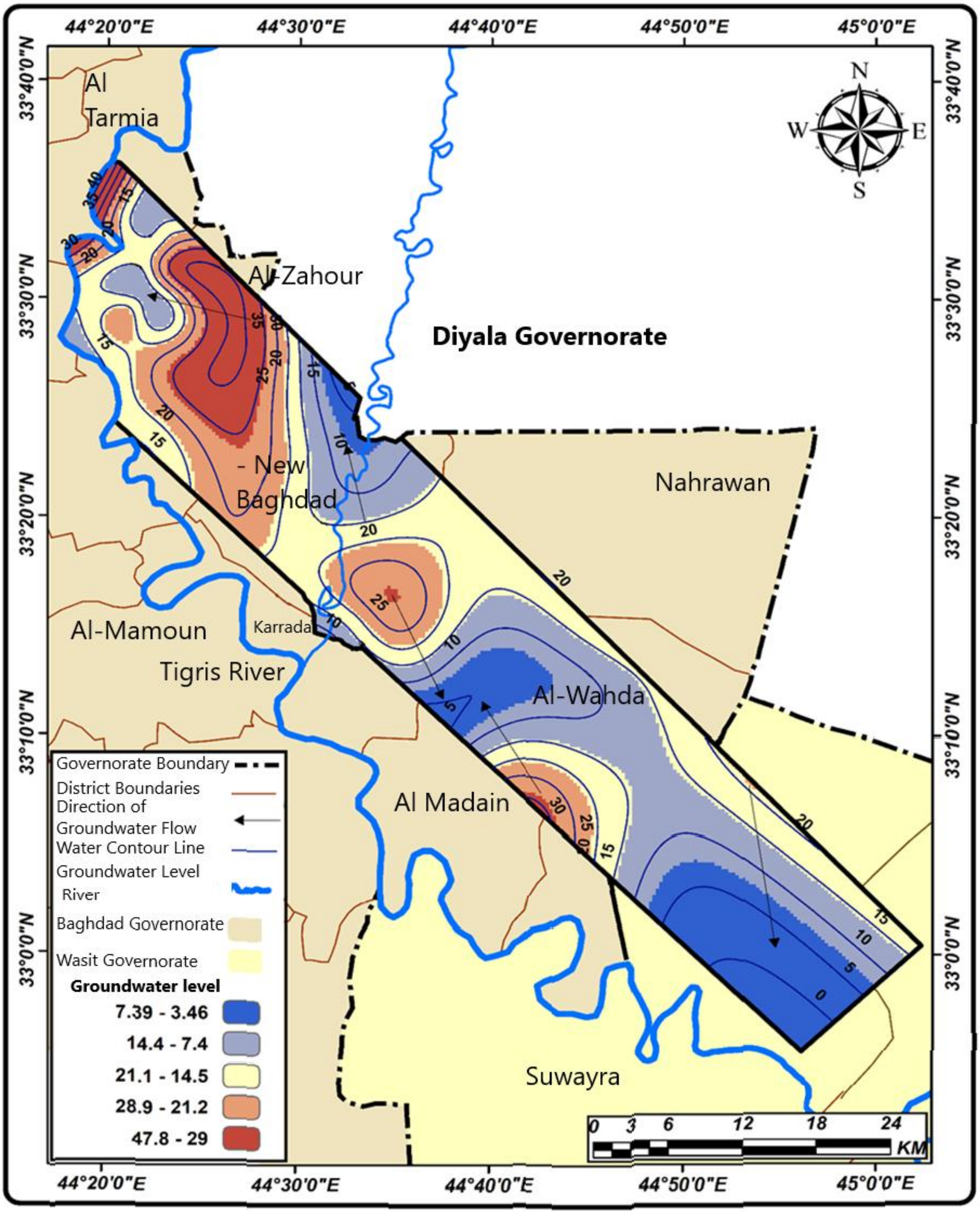
Map No. (3). Thegroundwater Movement in Study Area



Source: The researcher based on data from Table (1) and Arc GIS10.8, Density program.

Fixed Levels

The fixed water level is the level at which the water stops when the well is still (when water is drawn from it, whether by self-flow or by pumping) (Khalil, Muhammad Ahmad Al-Sayyid, 2005, p. 139).

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That is, the hydrostatic pressure is equal to the atmospheric pressure towards the groundwater surface and the fixed levels reached the highest value as shown in the table in the central region (7.0-6.66) liters/second in an area of (20.7352) km2 at a rate of (4.64103) % and indicated in purple. As for the lowest value, it reached (5.08-3.54) liters/second in an area of (16.9247) km2 at a rate of (3.78815) % and indicated in yellow.

The southern region reached the highest value (7.0-6.66) liters/second with an area of (369.457) km2 and a percentage of (43.9023) %, indicated in purple. The lowest value reached (7.0-6.66) liters/second with an area of (217.425) km2 and a percentage of (26.5552) %, indicated in yellow. As shown in Map (3) and Table No. (2).

Table No. (1). Static Water Level

Percentage (%)	Area (km²)	Range (mg/L)	Colour	Region
3.788152	16.92473	3.54–5.08	Yellow	Central
35.00855	156.4114	5.09–5.76	Brown	
56.56226	252.7092	5.77–6.65	Light Purple	
4.641032	20.73523	6.66–7.9	Purple	
100	446.7807			Total
26.55519	217.4251	3.54–5.08	Yellow	Southern
16.63663	136.2152	5.09–5.76	Brown	
12.906	105.6701	5.77–6.65	Light Purple	
43.90218	359.4565	6.66–7.9	Purple	
100	818.7668			Total

Source: Researcher's work based on Table (1) using Excel.

Moving Levels

The moving water level is the one that stabilizes at the groundwater and after water is withdrawn from it for a period, the water is flowing and continuous (Ali, Hajar Tahseen, 2013, p. 136). The highest value of the moving water level as shown in the table in the central region was (12.5-11.4) liters/second in an area of (34.41655) km2 and at a rate of (7.697917) %, indicated in olive color. As for the lowest value, it reached (10.1-8.58) liters/second in an area of (13.38046) km2 and at a rate of (2.992796) %, indicated in gray color. In the southern region, the highest value was (12.5-11.4) liters/second in an area of (132.7692) km2 and at a rate of (16.23142) %, indicated in olive green. The lowest value was (10.1-8.58) liters/second in an area of (48.61319) km2 and at a rate of (7.697927) %, indicated in gray. As shown in the map (2) and table (2).

Table No. (2). Moving Water Level

Percentage (%)	Area (km²)	Range (mg/L)	Colour	Region

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2.992796	13.38046	8.58–10.1	Gray	Central
45.75502	204.5657	10.2–10.7	Green	
43.55426	194.7264	10.8–11.3	Dark Green	
7.697917	34.41655	11.4–12.5	Olive	
100	447.0891			Total
5.9431	48.61319	8.58–10.1	Gray	Southern
25.4582	208.2422	10.2–10.7	Green	
52.36729	428.3523	10.8–11.3	Dark Green	
16.23142	132.7692	11.4–12.5	Olive	
100	817.9769			Total

Source: Researcher's work based on Table (1) using Excel.

Well Depths

The study of the depths of wells, their levels and their production capacity determine the extent to which these wells can be used and their efficiency for various uses. The purpose of studying the spatial analysis of groundwater is to determine the amount of groundwater, which is a basic factor in studying the depths of wells (Thank you, Sahar Farhan Ali, 2016, p. 62). The geology of the region and the nature of the rocks of the region have a great impact on determining the depths of wells because they also determine the porosity and sediments that allow surface water to pass through them into the ground. As for the percentage of the depth of the well, as shown in the table, the highest value in the central region was (25-21) m with an area of (67.9031) km2 and a percentage of (51.198892) %, indicated in blue. The lowest value was (14.8-10) m with an area of (6.360739) km2 and a percentage of (1.423737) %, indicated in light sky blue. As for the southern region, the highest value was (25-21) m with an area of (31.11093) and a percentage of (3.79987), indicated in blue, and the lowest value was (14.8-10) m with an area of (333.0973) km2 and a percentage of (40.684307) %, indicated in light sky blue. As shown in Table (3) and Map (3).

Table No. (3). The Well's Depth

Percentage (%)	Area (km²)	Range (m)	Colour	Region
1.423737	6.360739	10–14.8	Light Sky Blue	Central
21.95525	98.08805	14.9–18	Sky Blue	
61.42212	274.4116	18.1–20.9	Light Sky Blue	
15.19889	67.9031	21–25	Blue	
100	446.7635			Total
40.68431	333.0973	10–14.8	Sky Blue	Southern

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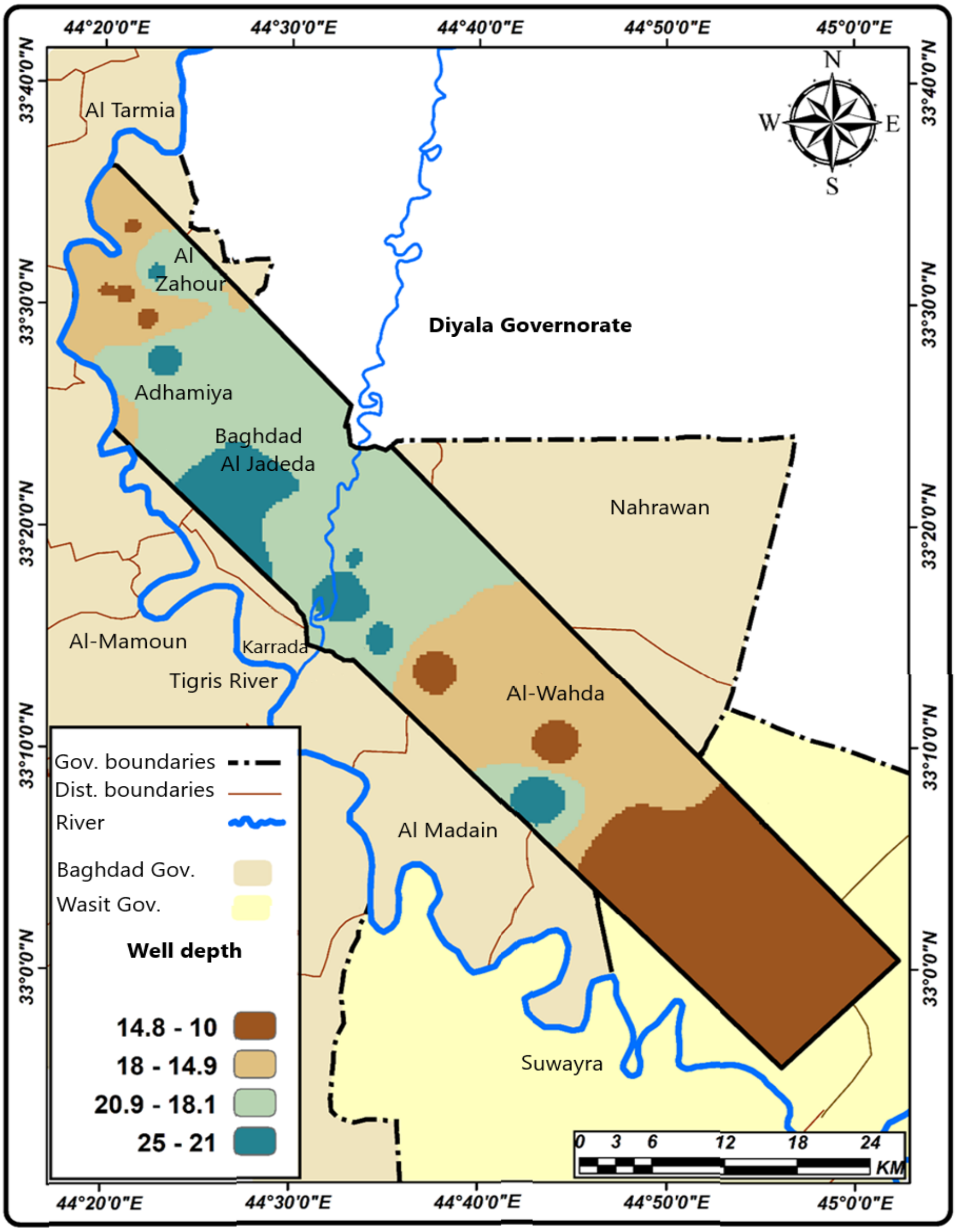
32.61185	267.0052	14.9–18	Light Sky Blue	
22.90397	187.5232	18.1–20.9	Deep Sky Blue	
3.79987	31.11093	21–25	Blue	
100	818.7366			Total

Source: Researcher based on Table (1) using Excel.

Map No. (4). Well Depths



Source: The Researcher based on Table (1) in Arc GIS 10.8, Geostatistical Analyst

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Production Capacity - Discharge

It is used to determine the amount of water produced from the well in the time it is poured into the well, whether by flow or pumping. The pumping rate is usually measured in liters/second or m3/minute (Al-Suwalifah, Fatima Muhammad, 2008, p. 123).

The study of well drainage is an important topic because it determines the source of the pouring rates from those wells according to a specific period and thus knowing the renewal of the economics of exploitation or investment to achieve its efficiency and the main goal of its establishment. The production capacity of the well varies from one well to another, and the reason for the variation in well productivity is the result of the interaction of human factors with natural factors, including the reservoir and the possibility of compensation in it, as well as the depth of the wells and the extent of the well's proximity and distance from the source of water supply (Al-Dulaimi, Naaman Latif Mahmoud, and Al-Jafeifi, Mahmoud Ibrahim Mutab, 2019, p. 27).

It is clear from Map (4) and Table (4) that the rate of production capacity varied from one well to another, depending on the capacity of the discharge wells, their depths, and how close they are to the water level of the groundwater storage, and depending on the type of pumps installed on the wells (Abdul Karim, Dalia, 2021, p. 147).

The highest value of well productivity, as shown in Table (), was in the central region (5.98-4.63) pumping liters/second or m3/minute, with an area of (2.43889) km2 and a percentage of (0.54556) % indicated in light olive color.

The lowest value was (2.39-2) with an area of (150.329) km2, at a rate of (33.6285) %, indicated in purple.

The southern region reached the highest value (5.98-4.63) pumping litres/second or m3/minute, with an area of (126.548) km2, at a rate of (15.4759) %, indicated in light olive green. The lowest value reached (2.39-2) with an area of (138.092) km2, at a rate of (30.89) %, indicated in purple.

Table No. (4). Well Productivity

Percentage (%)	Area (km²)	Range (m)	Color	Region
30.89	138.0924	2–3.39	Purple	Central
62.86119	281.0181	3.4–3.98	Dark Purple	
5.703252	25.49613	3.99–4.62	Light Olive	
0.545558	2.438892	4.63–5.98	Light Olive	
100	447.0455			Total
5.120298	41.86837	2–3.39	Purple	Southern
34.77267	284.334	3.4–3.98	Dark Purple	
44.6311	364.9458	3.99–4.62	Light Olive	
15.47594	126.5458	4.63–5.98	Olive	
100	817.694			Total

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Source: Researcher's work based on Table (1) using Excel.

Physical Properties of Well Water

Color Odor Taste

The color of the water results from an increase in the concentration of manganese ions, the concentration of dissolved iron, a decrease in dissolved oxygen, and humic compounds. The taste results from an increase in total dissolved solids (TDS), an increase in carbonate hardness, types of dissolved oxygen, and excessive bacterial activity (Hussein, Yahya Abbas, 1989, p. 139). The smell will usually result from the presence of decaying materials and the presence of fungi, which cause harm when organic materials mix with water, causing decomposition in it, in addition to the chemical materials that help change the taste of the water and reduce the suitability of the water for drinking, and change the taste of the water and acquire a smell from it, but it is suitable for agricultural activity if the chemical elements in it are balanced with their natural limits (Karant, K. R., 1992, p. 81).

Temperature

Temperature is one of the important properties of groundwater and refers to the increase or change in the temperature of water in a way that differs from the natural temperature. Temperature affects the properties of the density and taste of water and is linked to internal factors in terms of the degree of depth, interactions that occur with rocks, the nature of rocks and the structure containing water. It also affects the surface thermal system the closer it is to the surface, and vice versa. The amount of increase decreases the deeper the depth towards the earth's interior (Simmers, I., 1998, p. 3346). Water temperature also represents a factor that affects its ability to absorb a range of chemical pollutants and inorganic components (World Health Organization, n.d).

Salts (total dissolved solids)

It is the sum of the dissolved solids in the aqueous solution, whether ionized (salt) or non-ionized, remaining in the dried aqueous sample. It is also expressed as salinity and measured in milligrams per liter (parts per million myl Lcppnm), as it is considered a general indicator of water quality. The concentration and type of salts depend on the origin of the basin, its environment, and the water movement system in the groundwater reservoir. It is also a general indicator of the amount of salinity and the classification of groundwater. It depends on the type of rocks and the period required for the contact process between the rocks of the reservoir and the water and the percentage of dissolved materials. The quantities and distribution of dissolved salts (T.D.S.) vary according to geological conditions (Davis, S. N., & DeWiest, R. J., 1966, p. 6.).

The highest value of dissolved materials as shown in the table in the central region was (11,600-7,720) mg/L in an area of (30.60014) km2 and a percentage of (6.852205) %, indicated in red. The lowest value was (4,280-1,510) mg/L in an area of (47.30573) km2 and a percentage of (6.852205) %, indicated in sky blue. As for the southern region, the highest value was (11,600-7,720) mg/L in an area of (29.91638) km2 and a percentage of (3.66112) %, indicated in red, and the lowest value was (4,280-1,510) mg/L in an area of (148.738) km2 and a percentage of (18.19731) %, indicated in sky blue.

Table (5). International Salt Concentrations

Water Type	TDS Value (mg/L)
Freshwater	Less than 100

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Slightly Saline Water	Between 1000–3000
Moderately Saline Water	Between 3000–10000
Saline Water	Between 10000–35000
Very Saline Water	More than 35000

Source: Obaid Majeed, Ali Develop mint of turbine system for pumping Deep under, erg round Water, Iraq journal of desert, Studies, vil,2, no 2010, p32.

Table (6. Concentrations of Dissolved Substances

Percentage	Area (km²)	Range (mg/L)	Color	Region
8.331376	37.20573	1,510-4,280	Sky Blue	Central
14.09406	62.94037	4,290-5,500	Green	
33.63381	150.1997	5,510-6,450	Yellow	
37.08855	165.6277	6,460-7,710	Orange	
6.852205	30.60014	7,720-11,600	Red	
100	446.5737			Total
18.19731	148.738	1,510-4,280	Sky Blue	Southern
36.962	302.1135	4,290-5,500	Green	
23.38761	191.1615	5,510-6,450	Yellow	
17.79297	145.433	6,460-7,710	Orange	
3.660112	29.91638	7,720-11,600	Red	
100	817.3624			Total

Source: Researcher's work based on Table (1) using Excel.

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Electrical Conductivity (Ec)

It is a measure of the ability of an aqueous solution to conduct electric current. Water is a good conductor of electricity if it contains ionic concentrations based on ions and salts, as the relationship between salts and electrical conductivity is a direct relationship (Hussein, Dhimaa Adham, 2021, p. 171). That is, the more the number of salts increases, the more the electrical conductivity increases. The same is true for its relationship with temperature, that is, the more the temperature increases by one degree Celsius, the electrical conductivity increases by (2%) due to the increase in the ionization of salts in the water (Al-Khalidi, Arkan Radi, 1993, p. 58).

We find the highest value of electrical conductivity as shown in Table (7) in the central region, reaching (18,000-11,700) mm/liter, with an area of (44.13846) km2, at a rate of (9.878961) %, indicated in dark olive color.

The lowest value was (6.240-2.310) mm/L in an area of (31.06361) km2, at a rate of (6.952579) %, indicated in brown. As for the southern region, it was higher at a value of (18.000-11.700) mm/L in an area of (56.12354) km2, at a rate of (6.853468) %, indicated in dark olive. As for the lowest value, it was (6.240-2.310) mm/L in an area of (109.0134) km2, at a rate of (13.331476) %, indicated in brown.

From map (8:3), we find that the spatial distribution of conductivity is that wells have a very high percentage, which increases in the study area, due to some farmers discharging excess irrigation and drainage water into the streams, which causes groundwater levels to rise and evaporation to increase, which causes an increase in the electrical conductivity (Ec) percentage due to poor management of irrigation and drainage networks and leaving them without treatment and disinfection (Thank you, Sahar Farhan Ali, 2016, p. 81).

Table (7). Electrical Conductivity

Percentage	Area (km²)	Range (mg/L)	Color	Region
6.952579	31.06361	2,310-6,240	Brown	Central
12.60369	56.31237	6,250-8,150	Light Brown	
25.39208	113.4499	8,160-9,810	Green	
45.17269	201.8282	9,820-11,600	Olive	
9.878961	44.13846	11,700-18,000	Dark Olive	
100	446.7926			Total
13.33148	109.0134	2,310-6,240	Brown	Southern
18.94566	154.9213	6,250-8,150	Light Brown	
36.46488	298.1785	8,160-9,810	Green	
24.39452	199.4774	9,820-11,600	Olive	

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6.863468	56.12354	11,700-18,000	Dark Olive	
100	817.7141			Total

Source: Researcher's work based on Table (1) using Excel.

PH

It is known as a measure of alkalinity and acidity under normal conditions of temperature and pressure. It is the direct influence in classifying water quality. It is one of the important factors in chemical reactions. Its values are determined from (0-14) (Gpyne, D., 201, p. 174). The value between (0-7) means that the medium is alkaline, and the water is ideally sweet if the value reaches (7), i.e. the neutrality degree. The highest value of the pH element, as shown in table No. (8) in the central region is (7.73-8.278) with an area of (4.61594) km2 and a percentage of (1.030829) %, indicated in blue. As for the lowest value, it is (7.244-7.101) with an area of (311.812) km2 and a percentage of (69.63357) %, indicated in red.

The highest value was (7.73-8.278) with an area of (1.95644) km2, at a rate of (0.238771) %, indicated in blue. The lowest value was (7.244-7.101) with an area of (635.67) km2, at a rate of (77.57962) %, indicated in red.

We find that the samples are within the permissible limits and did not exceed these limits. The reason is due to the feeding process, which reduces the percentage of CO2, which is one of the reasons for the high pH value. We also notice in the map the concentration of pH at lower levels in most of the study area.

What indicates that these are wells is that they are of a basic nature, meaning that they are suitable for use for drinking and irrigating agricultural lands, as the people of this region depend on them for agriculture as well as for watering animals, especially in the lean season or the summer season.

There are damages that are predominantly alkaline and unsuitable for use and are spread in two study areas. Especially in places where there are industrial activities as well as human activities and agricultural activities that use pesticides that affect the degree of hydrogen concentration (Al-Ibrahimi, Suhaila, 2021).

Table (8). Ph Concentration

Percentage	Area (km²)	Range (mg/L)	Colour	Region
69.63357	311.8116	7.101-7.244	Red	Central
26.76513	119.8514	7.245-7.415	Light Brown	
2.570473	11.5103	7.416-7.729	Gray	
1.030829	4.61594	7.73-8.278	Blue	
100	447.7892			Total
77.57962	635.6702	7.101-7.244	Red	Southern
19.21173	157.4166	7.245-7.415	Light Brown	

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2.96988	24.33453	7.416-7.729	Gray	
0.238771	1.956436	7.73-8.278	Blue	
100	819.3778			Total

Source: Researcher's work based on Table (1) using Excel.

Positive Chemical Properties of Well Water

Calcium (Ca)+: Calcium is one of the main positive ions in groundwater and one of the most important basic elements for animals and plants. It is an alkaline element whose main source is sedimentary rocks that contain calcium, such as gypsum and limestone (Al-Zubaidi, Sundus Muhammad Alwan, 1987, p. 42). The presence of calcium in water in appropriate quantities is not harmful but rather helps maintain human health and reduces the rate of fasting in water used for agricultural purposes. The highest value of the calcium element, as shown in the table, is in the central region, ranging between (1,112-600.9) mg/L in an area of (78,80915) km2 and at a rate of (19.6476) %, represented by the red color. The lowest value is (252.5-16.07) mg/L in an area of (160,9542) km2 and at a rate of (36,01388) %, represented by the blue color. In the southern region, the value ranges from (1,112-600.9) mg/L in an area of (99,15792) km2, at a rate of (12,11339) %, represented in red. The lowest value is (252.5-16.07) mg/L in an area of (371,2654) km2, at a rate of (45,35455) %, represented in blue.

Table No. (9). Calcium Concentration (Ca)+

Percentage	Area (km²)	Range (mg/L)	Color	Region
36.01388	160.9542	16.07-252.5	Blue	Central
25.00249	111.7418			
19.33614	86.41759	450.4-600.8	Orange	
19.6475	87.80915	600.9-1112	Red	
100	446.9228			Total
45.35466	371.2645	16.07-252.5	Blue	Southern
28.97493	237.1832	252.6-450.3	Green	
13.55702	110.9752	450.4-600.8	Orange	
12.11339	99.15792	600.9-1112	Red	
100	818.5808			Total

Source: Researcher's work based on Table (1) using Excel.

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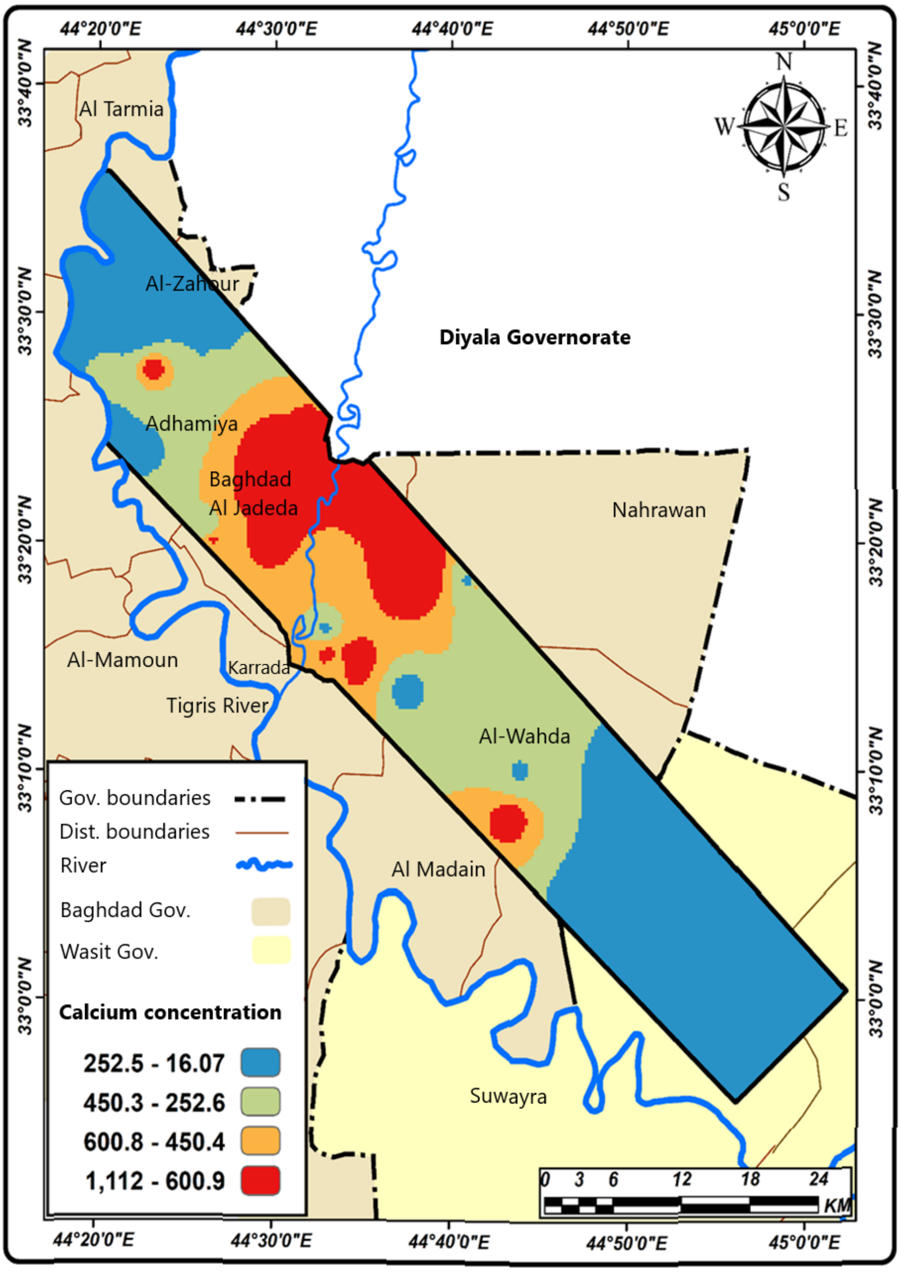
Map (5). Calcium Concentration (Ca)+



Source: The researcher based on table (1) and ArcGIS10.8 Geostatistical Analyst.

Magnesium+(mg)

Magnesium is a chemical element classified as a positively charged ion and one of the alkaline earth metals. It is one of the primary cations found in groundwater and is essential for animal and plant nutrition. The presence of magnesium ions in water originates from the dissolution of rocks and minerals that contain magnesium in their composition, such as dolomite, limestone, lime, clay minerals, and sedimentary rocks (Hem, J. D., 1989, p. 97).

Regarding magnesium concentration, the highest value recorded in the central region, as shown in the table, ranges from 2.564 to 4.094 mg/L, covering an area of 29.66099 km², which constitutes 6.635012% of the

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region and is represented by dark red (Al-Ibrahimi, Suhaila, 2019, p. 1872). The lowest concentration ranges from 0.152 to 0.9558 mg/L, covering an area of 91.80823 km², equivalent to 20.53703%, and is represented by yellow.

In the southern region, the highest concentration ranges from 2.564 to 4.094 mg/L, covering an area of 0.723669 km², which constitutes 0.088371% of the region and is represented by dark red. The lowest concentration ranges from 0.152 to 0.9558 mg/L, covering an area of 91.80823 km², equivalent to 20.53704%, and is represented by yellow.

Table No. (10). Magnesium concentration + (mg)

Percentage	Area (km²)	Range (mg/L)	Color	Region
20.53703	91.80823	0.152-0.9558	Yellow	Central
53.2815	238.1883	0.9559-1.59	Orange	
19.54646	87.38	1.591-2.563	Red	
6.635012	29.66099	2.564-4.094	Deep Red	
100	447.0375			Total
61.39834	502.7892	0.152-0.9558	Yellow	Southern
38.51329	315.3842	0.9559-1.59	Orange	
		1.591-2.563	Red	
0.088371	0.723669	2.564-4.094	Deep Red	
100	818.8971			Total

Source: Researcher's work based on Table (1) using Excel.

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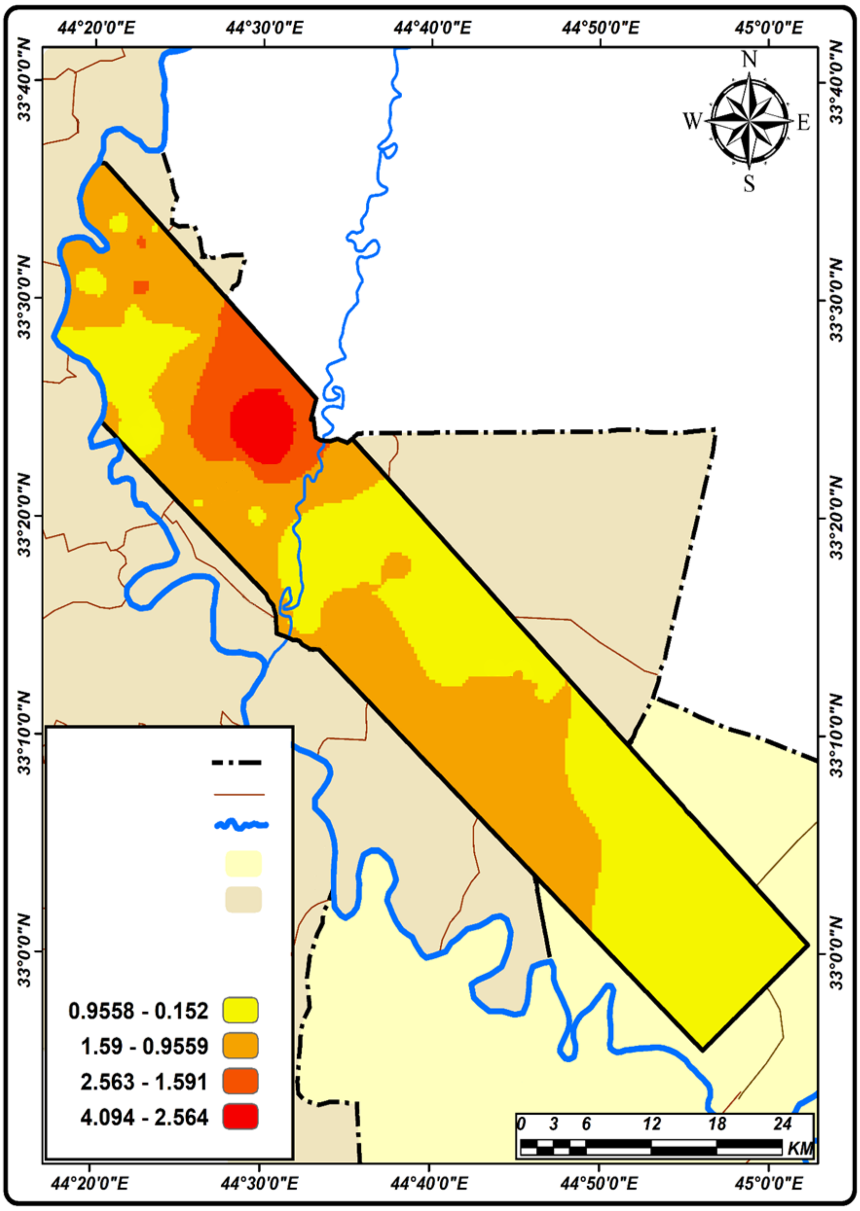
Map (6). Magnesium Concentration + (Mg)



Source: The researcher based on Table (1) in Arc GIS 10.8 Geostatistical Analysts.

Sodium: Na+

Sodium is one of the most abundant metallic ions in nature and exhibits a high solubility in water. It is typically associated with halite rocks, such as sodium chloride (NaCl), and is released through the weathering of clay minerals. This process liberates significant quantities of sodium ions due to ion exchange interactions with magnesium and calcium. Human activities also play a significant role in sodium concentration, particularly through the use of salts in recycling wastewater for irrigation and domestic purposes (Raouf, Diaa Baheej, 2019, p. 172).

In the central region, the highest sodium concentration, as shown in Table (), ranges from 966.3 to 1.706 mg/L, covering an area of 47.19017 km², equivalent to 10.560857%, and is represented by dark brown. The lowest sodium concentration ranges from 51.21 to 395.1 mg/L, covering an area of 164.9605 km², equivalent to 36.917098%, and is represented by light brown.

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In the southern region, the highest sodium concentration ranges from 966.3 to 1.706 mg/L, covering an area of 47.86895 km², equivalent to 5.850584%, and is represented by dark brown. The lowest concentration ranges from 51.21 to 395.1 mg/L, covering an area of 434.9605 km², equivalent to 53.069466%, and is represented by light brown.

Table No. (11) Sodium Concentration (Na)+-

Percentage	Area (km²)	Range (mg/L)	Color	Region
36.9171	164.9605	51.21-395.1	Brown	Central
23.28296	104.0377	395.2-687.2	Dark Brown	
29.23908	130.652	687.3-699.2	Walnut	
10.56086	47.19017	966.3-1,706	Dark Walnut	
100	446.8404			Total
53.06947	434.2096	51.21-395.1	Brown	Southern
24.59031	201.1957	395.2-687.2	Light Brown	
16.48964	134.9168	687.3-699.2	Walnut	
5.850584	47.86895	966.3-1,706	Dark Walnut	
100	818.1911			Total

Source: *Researcher's work based on Table (1) using Excel.*

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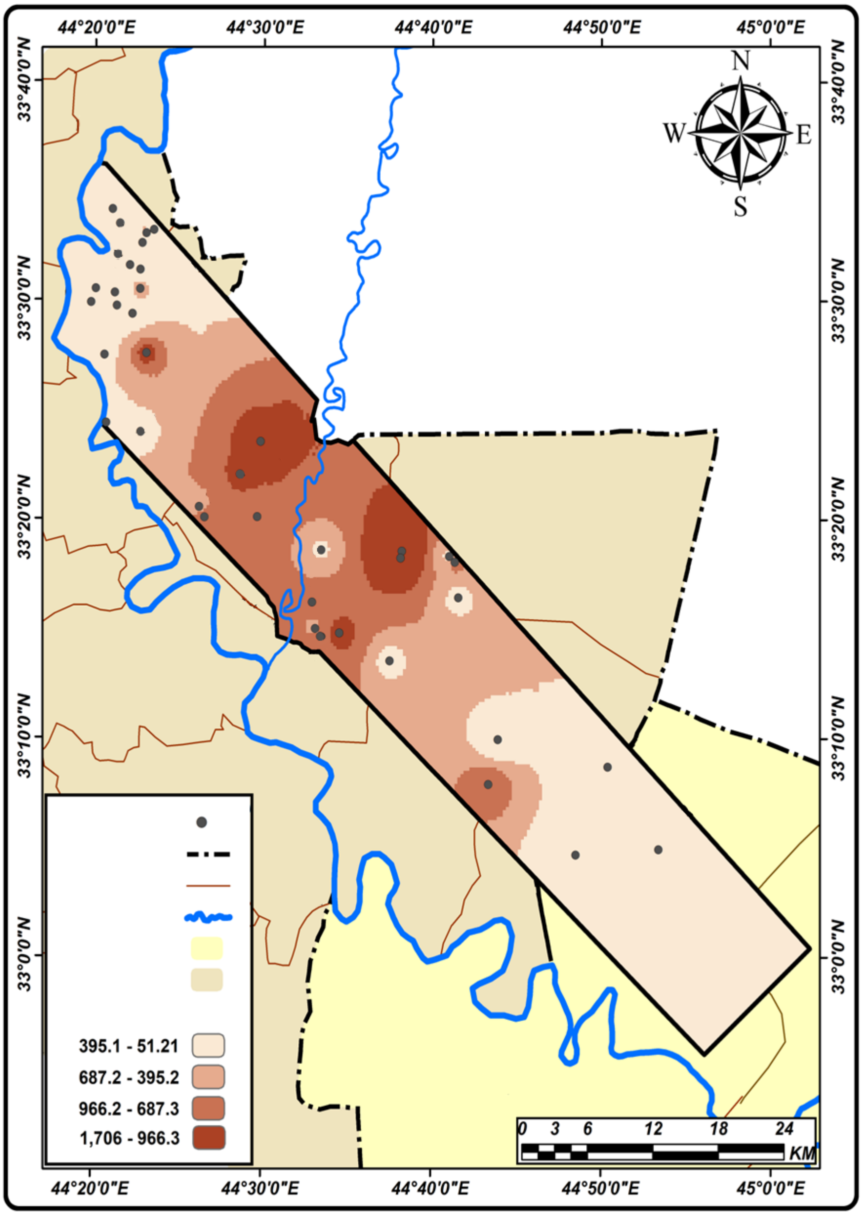
Map (7) Sodium Concentration Na



Source: The researcher based on Table (1) in Arc GIS 10.8 Geostatistical Analyst program.

Potassium (k)

Potassium is one of the less common ions in water and is a positively charged chemical element primarily sourced from clay minerals, feldspar, and mica. It is most abundant in sedimentary rocks, and most potable water contains less than 15 parts per million (ppm) of potassium. Chemical fertilizers can increase its concentration, which is highly beneficial for crops at specific levels. Potassium's presence in groundwater is attributed to its occurrence in minerals associated with subsurface layers (Maneh, Jawad Kazem, 2003, p. 45).

As shown in Table (12), in the central region, the highest potassium concentration ranges from 99.45 to 196 mg/L, covering an area of 18.80072 km², equivalent to 4.202666%, represented in green. The lowest concentration ranges from 0.6015 to 42.72 mg/L, covering an area of 227.991 km², equivalent to 50.96455%, represented in pink.

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In the southern region, the highest concentration ranges from 99.45 to 196 mg/L, covering an area of 49.23235 km², equivalent to 6.015814%, represented in green. The lowest concentration ranges from 0.6015 to 42.72 mg/L, covering an area of 437.1672 km², equivalent to 50.96455%, represented in pink.

Table No. (12): Potassium Concentration (K)

Percentage	Area (km²)	Range (mg/L)	Color	Region
50.96455	227.991	0.6015-42.74	Pink	Central
28.57088	127.8124	42.75-68.03	Light Pink	
16.26191	72.74801	68.04-99.44	Light Green	
4.202666	18.80072	99.45-196	Yellow	
100	447.3521			Total
53.41723	437.1572	0.6015-42.74	Pink	Southern
21.03191	172.1214	42.75-68.03	Light Pink	
19.53504	159.8713	68.04-99.44	Light Green	
6.015814	49.23235	99.45-196	Green	
100	818.3823			Total

Source: Researcher's work based on Table (1) using Excel.

Negative Chemical Properties

Chlorides Cl

Chloride ion is one of the primaries negatively charged ions in water, contributing to a salty taste when combined with other ions like calcium. The sources of chloride are varied, including potassium fertilizers, animal waste, industrial effluents, and climatic factors. The concentration of chloride tends to be higher in arid regions and lower in humid areas (Al-Jubouri, Dumiya Adham Hussein, 2015, p. 114).

As shown in Table (), in the central region, the highest chloride concentration ranges from 1300 to 2568 mg/L, covering an area of 96.584 km², which represents 21.62685% of the region and is indicated by light green. The lowest concentration ranges from 99.5 to 525.2 mg/L, covering an area of 241.272 km², which represents 31.618267%, indicated by red.

In the southern region, the highest chloride concentration ranges from 1300 to 2568 mg/L, covering an area of 98.3277 km², equivalent to 12.011997%, represented in light green. The lowest concentration ranges from 99.5 to 525.2 mg/L, covering an area of 506.269 km², which accounts for 49.630957%, represented in red.

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Table No. (13) Chlorine Element Concentration CL

Percentage	Area (km²)	Range (mg/L)	Color	Region
31.61827	141.2724	99.5-525.2	Red	Central
23.70037	105.8947	525.3-921.9	Light Red	
23.06451	103.0536	922-1299	Green	
21.61685	96.58541	1300-2567	Light Green	
100	446.8061			Total
49.63096	406.2685	99.5-525.2	Red	Southern
24.54013	200.8803	525.3-921.9	Light Red	
13.81692	113.1024	922-1299	Green	
12.012	98.32767	1300-2567	Light Green	
100	818.5789			Total

Source: Researcher's work based on Table (1) using Excel.

Sulphates SO4

It is one of the most important negative chemical elements resulting from the presence of sulfates in groundwater and from the oxidation of sulfur ores due to the dissolution of evaporated rocks anhydrite (CaSO4) and gypsum (Cos4.2H2o). It also contains gypsum and sodium sulfate. It does not exceed (20) mg/liter in drinking water, which causes a difference in the normal taste of drinking water. The reason for the high percentage of sulfates in the study area is the presence of gypsum, in addition to irrigation and drainage water, which produces varying amounts of sulfur that seep into the ground (Ne'ma, Jihan Ali Abdel, 2022, p. 196).

As for the sulfate element So4, the highest value was reached as shown in the table in the central region (3.815-2.177) mg/L with an area of (62.4619) km2 and a percentage of (13.9727) %, indicated in dark blue. The lowest percentage was (812.7-116.5) mg/L with an area of (150.329) km2 and a percentage of (33.6285) %, indicated in light sky blue. As for the southern region, the highest percentage was (3.815-2.177) mg/L with an area of (44.2023) km2 and a percentage of (5.40073) %, indicated in dark blue. The lowest value was (812.7-116.5) mg/L in an area of (408.787) km2 and at a rate of (49.9456) %, indicated in light sky blue.

Table No. (14) Concentration of Sulfates SO4

Percentage	Area (km²)	Range (mg/L)	Color	Region
33.62851	150.3293	116.5-812.7	Light Sky Blue	Central

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25.09762	112.1937	812.8-1509	Light Sky Blue	
27.30121	122.0444	1510-2176	Blue	
13.97266	62.46188	2177-3815	Dark Blue	
100	447.0292			Total
49.9465	408.7869	116.5-812.7	Light Sky Blue	Southern
28.54429	233.6207	812.8-1509	Light Sky Blue	
16.10848	131.8398	1510-2176	Blue	
5.400726	44.20222	2177-3815	Dark Blue	
100	818.4497			Total

Source: Researcher's work based on Table (1) using Excel.

Nitrates NO3

Nitrate is a negatively charged ion that contributes significantly to groundwater pollution. It consists of one nitrogen atom and three oxygen atoms, with the chemical formula (NO_3). While generally inert, nitrate is converted into nitrite by bacteria or enzymes within the human body. Its primary sources in nature include the atmosphere, chemical fertilizers used in agriculture, vehicle emissions, plants (legumes and vegetables), animal waste, decaying plant matter, industrial water waste, and domestic sewage. The natural concentration of nitrate in rainfall ranges from 0.1 to 0.3 mg/L, with typical concentrations in groundwater varying between 0.1 and 10 mg/L. For drinking water, nitrate levels should not exceed 25 mg/L to avoid adverse effects on human health (Hamadeh, Safi Aswad Hamoudi, 2008, p. 53).

As shown in Table (), the highest nitrate concentration in the central region ranged between 1.8–1.5 mg/L, covering an area of 24.52771 km², accounting for 5.48097% of the region, represented by light blue. The lowest concentration ranged between 0.4–0.1 mg/L, covering an area of 43.14971 km², equivalent to 9.642249%, represented by red.

In the southern region, the highest nitrate concentration was between 1.4–1.1 mg/L, covering an area of 3.682612 km², representing 0.44975%, indicated by light blue. The lowest concentration was 0.4–0.1 mg/L, covering an area of 434.8432 km², which represents 53.08715%, indicated by red.

Table No. (15): Nitrate Concentrations NO3

Percentage	Area (km²)	Range (mg/L)	Color	Region
9.642249	43.14971	0.1-0.4	Red	Central
66.80096	298.9388	0.5-0.9	Yellow	
18.07583	80.89053	1.1-1.4	Blue	
5.48097	24.52771	1.5-1.8	Sky Blue	

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100	447.5067			Total
53.08715	434.8322	0.1-0.4	Red	Southern
46.46337	380.5774	0.5-0.9	Yellow	
0.449475	3.681612	1.1-1.4	Blue	
100	819.0913			Total

Source: Researcher's work based on Table (1) using Excel.

Bicarbonate HCO3

A negatively charged chemical element, carbonate ions are introduced into groundwater primarily through rainwater containing carbon dioxide (CO_2), which originates from the atmosphere. Additionally, carbonates are present in the soil and are converted into bicarbonates when the pH drops below 8.2. The presence of bicarbonates is essential for irrigation; however, excessive accumulation in the soil increases sodium levels, leading to clogged soil pores and reduced soil permeability (Hussein, Ahmed, 2013, pp. 114–115).

As shown in Table (), the highest carbonate concentrations in the central region ranged from 1,524 to 940.3 mg/L, covering an area of 65.3645 km², accounting for 14.624265% of the region, represented by light olive green. The lowest concentration ranged from 320.9 to 20.06 mg/L, covering an area of 155.431 km², equivalent to 34.775316%, represented by light green.

In the southern region, the highest concentrations were between 1,524 and 940.3 mg/L, covering an area of 38.9856 km², representing 4.764273%, indicated by olive green. The lowest concentrations were between 320.9 and 20.06 mg/L, covering an area of 412.46 km², accounting for 51.504974%, indicated by light green.

Conclusions

It can be concluded that the laboratory analyses conducted on samples taken from two different fields (the southern region and Al-Rashidiya), totaling 30 samples, provide a comprehensive understanding of the groundwater characteristics in these areas and help in identifying the variations between them.

The study of well depths and their production capacity is essential for assessing the efficiency of wells and their ability to meet diverse usage needs. Well depths are significantly influenced by geological structures and the nature of the rocks, which determine porosity and deposits that facilitate water infiltration into the subsurface. The results showed a noticeable variation in well depths between the central and southern regions, with the central region exhibiting greater depths ranging between 21 and 25 meters, while wells in the southern region were shallower. Moreover, the production capacity of wells is affected by factors such as depth and the geographical characteristics of each area.

The study reveals significant variations in groundwater characteristics, such as salinity, electrical conductivity, and pH levels. The total dissolved solids (TDS) values varied between the central and southern regions, with the central region recording higher salinity levels. Similarly, electrical conductivity values differed between the regions, with the highest levels observed in the central region. As for pH levels, they remained within permissible limits, indicating the suitability of water for agricultural and drinking purposes in most areas.

The data indicate that human activities, such as irrigation water discharge and the drainage of excess water, directly influence the increase in groundwater electrical conductivity. Furthermore, some areas experiencing industrial and agricultural activities may be subject to pH fluctuations, potentially affecting the water's suitability in these regions.

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Based on the extracted results, it is recommended to conduct continuous monitoring of pollution levels and the environmental impact on groundwater. Effective management techniques for irrigation and drainage networks should also be developed to improve water management. Additionally, industrial and agricultural activities that may contribute to water contamination should be minimized, and strategies to enhance groundwater quality should be adopted to ensure sustainable use across various fields.

Some wells are deemed suitable for agricultural use, particularly for crops such as palm trees and summer vegetables.

Certain wells exhibit low to moderate salinity, making them suitable for cultivating salt-tolerant crops like wheat and barley.

Other wells are unsuitable for agricultural use due to their high salinity levels.

Regarding chemical elements such as calcium, magnesium, potassium, and nitrates, their levels were found to be within permissible limits.

Concerning chlorides, the study showed that half of the wells fell within permissible limits, while the other half exceeded them.

As for sulfates and carbonates, the permissible limits were exceeded in all wells.

The study indicates that oil wells do not directly impact groundwater wells. However, the effect of oil is confined to the soil surface, where drilling residues containing hydrocarbons—among the most hazardous pollutants—are deposited. Other environmental impacts, such as radioactive and air pollution, also have adverse effects on plants and humans, causing severe diseases.

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(*) Drawdown (Drow Dawn): Refers to the separation limit of water levels during water pumping or discharge from a flowing well. It is the difference in meters between the static water level and the pumping water level.
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