Geological and Hydrogeological Characteristics of Umm Er Radhuma aquifer West of Iraq

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ABSTRACT

Umm Er Radhuma formation extension covers most parts of the Western Desert excluding Al Rutba uplift. It has been newly sub-divided into two members. The first member (Lower member of Middle Paleocene**)** and the second member (Upper member of Upper Paleocene). Umm Er Radhuma aquifer consists of two types of aquifers: The first is an unconfined aquifer that covers an area of (60,068) km^2, while the second is a confined aquifer which is normally found in the eastern and the north-eastern parts of the Northern Desert and most parts of the Southern Desert. It covers an area of (91,766) km^2. The total extension area of the formation in the Desert is about (151,834) km^2.

The value of its transmissivity coefficient varies between (3) m^2 / day to (2100) m^2 /day reflecting a highly heterogeneous aquifer due to the variations in its fractures density and rock porosity. The storage coefficient values for the confined aquifer may attain a value of (1.2×10^{-4}) in well KH12 / 7, while in Takhadid well the value of the specific yield is (2.45×10^{-2}) for the unconfined aquifer. (123.196535×10^9 m^3), while it is The storage of Umm Er Radhuma unconfined aquifer is (152.26838×10^9 m^3) for the confined aquifer. The total storage of Umm Er Radhuma aquifer is (275.464915×10^9 m^3).

الخلاصة

يغطي امتداد تكوين أم أرضمة أكثر أجزاءِ الصحراءِ الغربية ماعدا نهوض الرطبة ومعظم الصحراء الجنوبية. تكوين أم أرضمة يقسم إلى جزئين الجزء الأول (الجزء الأسفل- البلايستوسين الأوسط) والجزء الثاني (الجزء الأعلى- البلايستوسين الأعلى) .

يتألف تكوين أم أرضمة من نوعين من المكامن: الأول المكمن الغير محصور الذي يغطي مساحة قدرها (60,068) كم^2، بينما الثاني المكمن المحصور الذي يوجد في الأجزاءِ الشرقية والشمالية الشرقية للصحراءِ الشمالية وأكثر أجزاءِ الصحراءِ الجنوبية والذي يغطي مساحة قدرها (91,766) كم^2.المساحة الكلية للتكوين في الصحراءِ الغربية هي (151,834) كم^2. تتفاوت قيمة معامل الناقلية بين (3) م^2/ يوم إلى (2100) م^2/ يوم حيث تعكس عدم تجانس المكمن الجوفي بسبب الاختلاف في كثافة الشقوق ومسامية الصخور. تم حساب قيمة معامل الخزن للمكمن المحصور في بئر KH12/7 وجد بأنه يساوي (1.2×10^{-4}) في حين حسب التصريف النوعي للمكمن الغير محصور في بئر تخاديد وجد بأنه يساوي (2.45×10^{-2}).تم حساب الخزين للمكمن الغير محصور وجد بأنه يساوي (123.196535×10^9 m^3)، بينما هو (152.26838×10^9 m^3) للمكمن المحصورةِ، وبذلك يكون الخزين الكلي لمكمن أم أرضمة هو (275.464915×10^9 m^3).

مستل من أطروحة دكتوراه

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Introduction:

The studied area is located between the Euphrates river and the Saudi Arabian borders, it forms about (151,834) km^2 of the Iraqi Western Desert covering Umm Er Radhuma geological formation inside Iraq, figure (1), which is often considered of a great importance in the Iraqi Desert as well as in Saudi Arabia.

Figure (1) Location map

Purpose of Study:

Umm Er Radhuma aquifer is considered as a major aquifer in the Iraqi western desert and a potential regional transboundary aquifer shared with Saudi Arabia and Kuwait. Its importance to Iraq is due to its vast extension and its location near the surface of the ground as well as to its groundwater quality which is considered relatively good compared to other aquifers in the western desert. The high variability of the aquifer system, storage of the groundwater and recharge condition and the way of managing of this aquifer resource is yet to be accomplished. The aim of this study is therefore to analyse available geological and hydrogeological information in order to understand the behavior of Umm Er Radhuma aquifer system. This will include:

1. Determining Umm Er Radhuma aquifer extension and its geological setting.
2. Studying the variations of its hydrogeological specifications.
3. Evaluating the aquifer storage and recharge.

Topographical the northern and southern deserts are generally flat regions, rising in elevation westwards in the northern desert and southwards in the southern desert. The main landscape is plateaus that are dissected by dense valleys, hills and depressions. The topographic gradient of the northern desert increases from the east to the west and from the northeast to the southwest in the

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southern desert in an average of 5 m/km, the lowest and highest points in the area are (25m and 400m a.s.l) Figure (2).

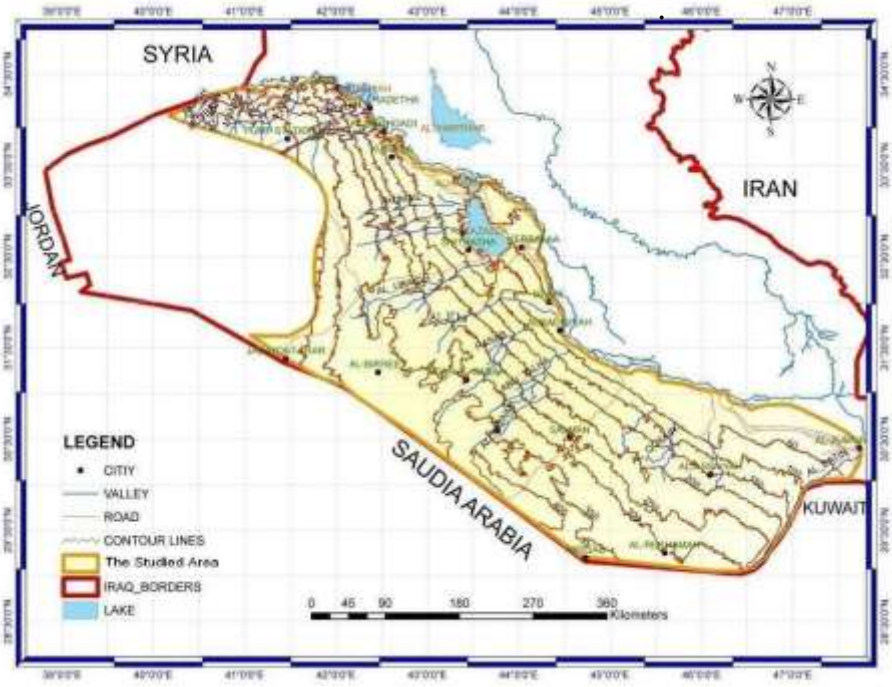

Figure (2) Topographical map

Geologically Umm Er Radhuma formation in the Western Desert has been newly sub-divided into two members. The first member (Lower member of Middle Paleocene**)** can further be sub-divided into two rock units according to the lithological and physical properties**:** Lower chalky unit and Lower shelly unit**.**

The second member (Upper member of Upper Paleocene) can be sub- divided into three rock units according to the lithological and physical properties**:** Shelly - chalky unit, Upper chalky unit and Upper shelly unit Figure (3).

Method of Study:

1- Hydrogeological data bank was used. These data are precisely documented until 1988.Further data for the wells which were drilled in the area in 2006 to 2009 were added.
2- GIS (V. 9.1) was used to draw the maps using 3D spatial analysis .
3- Collecting and processing hydrogeological cross sections data based on hydraulic data of drilling wells by using the GMS program version 6.

The thickness of Umm Er Radhuma formation differs from place to another, the largest thickness of the formation reaches to (500m) in the southern desert around Salman area and the south-east of the southern desert. This thickness decreases towards the east and the north-west of this region and the thickness reaches to less than (50) m in the north of Al Razzaza Lake and south of Al Qadisiyah dam Lake , Figure (4).

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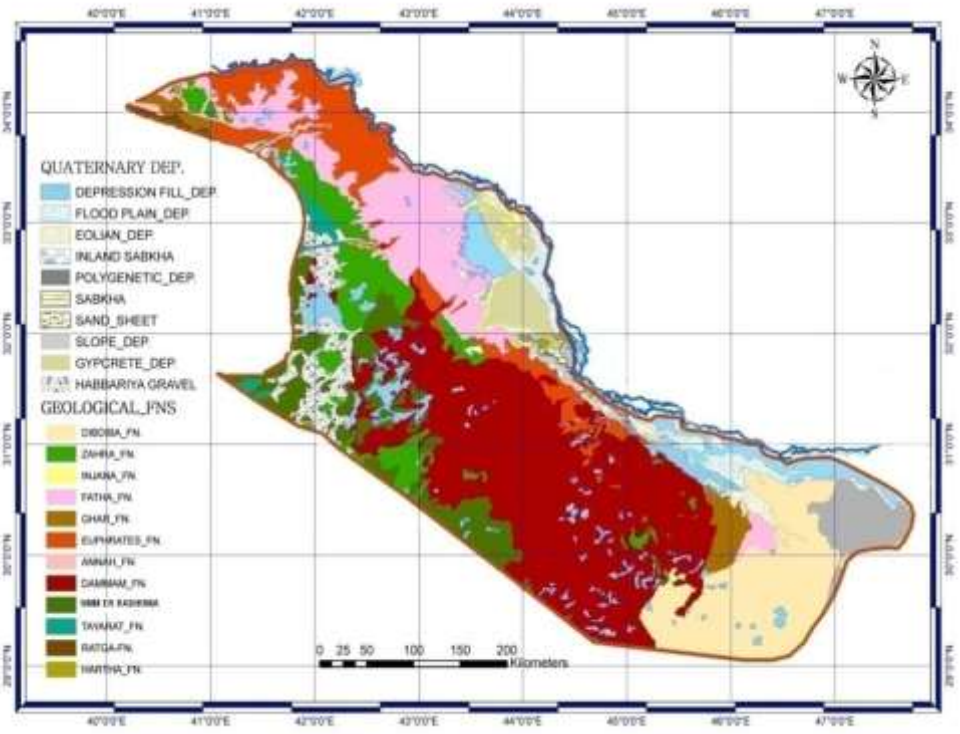

Figure (3) Geological map

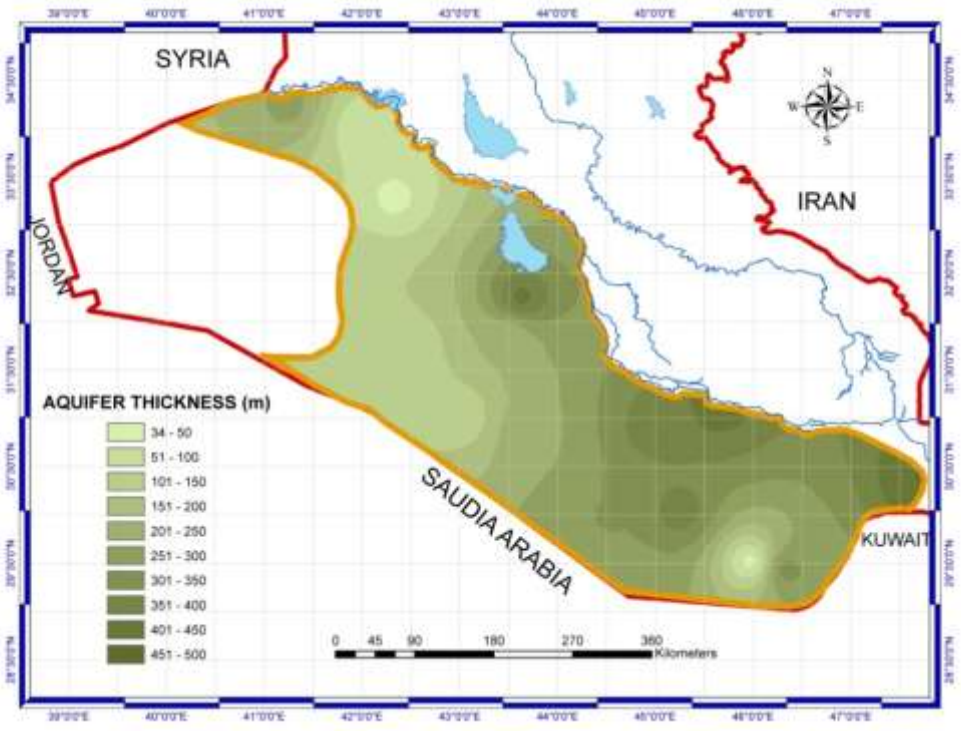

Figure (4) Thickness of Umm Er Radhuma

The formation gets thinner towards the west and the northwest of the outcrop area and on the south and the southwest of Rutba uplift in the western desert (Buday,1980). As the map (4) shows the extensive thickness of the formation in the western desert and shows the disappearing areas around Rutba uplift and toward the Iraqi- Jordanian –Saudi Arabia borders. From the map

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it is noticed that the thickness of the formation changes from lesser thickness in the north of the western desert and around Rutba uplift and has the largest thickness in the southern desert, specifically in the areas of Salman and the south east of the southern desert, where it reaches to 500 meters. It seems that the Euphrates river marks the end of the normal boundary of the formation to the east where it becomes deeper at the bottom of the river towards the sedimentary plain. While Rutba uplift is considered as the natural boundary of the formation from the west due to the erosion of the cropped layers.

Stratigraphical position: -

The lower contact: In the western desert section, Umm Er Radhuma formation overlies the Tayarat formation with an unconformity. In the eastern parts the contact is marked by the appearance of black and dark brown chert horizons or geodes, whereas in the western parts it is marked by sandstones and red gypsiferous claystones. At the central part of the western desert the contact is located on the top of the silicified desert varnished-limestone (Jassim et.al.,1984). The lower contact is not exposed in the southern desert with limited exposure in wadi Tabbel and Ubaidat areas. In the boreholes of British petroleum and National Oil Companies in southern Iraq as well as in the boreholes of hydrogeological investigation of blocks (1,2,3) by GEOSURV,1983 Umm Er Radhuma is underlain by Tayarat formation with unconformity, however, description of core bore taken from Ansab- borehole (KH-6) gives the impression of a seemingly conformable sequence. In this particular borehole the contact may be conformable and was taken to be the top of a black bituminous claystone bed (Tamr -Agha ,1984).

-The upper contact:

The upper contact of Umm Er Radhuma formation with the overlying Ubaiydh unit of Dammam formation is marked by (3-3.5) meters of thickness of basal conglomerate at wadi Al Ubaiyidh , whereas in other localities, south of Al-Nukhaib town , around Mdacece , Shabwan and Ghar villages, the contact is marked by (1-1.5) meters of thickness of ferruginous quartzitic sandstone and geodes. In Al Salman area , at Tal Gurabiya , Tar Al Lagahaiya, Tar Al Mafaky, Tar Shinnana, and Tar Al Leefiyah, the contact is marked by thick black and dark brown chert layers, nodules and geodes fragments , and phosphatic siliceous limestone (or phosphatic siliceous dolostone).In the southern desert , the upper contact of Umm Er Radhuma formation with the overlying Wagsa unit of Dammam formation is marked by (Yacoub and Hamid, 2001):

- Different beds of different levels of the upper shelly unit of Umm Er Radhuma formation (at the same level) are in contact with the overlying Dammam formation.
- A quick change of dip is at the contact of Umm Er Radhuma formation with the overlying Dammam formation.
- The presence of thick black chert layer, nodules and geodes fragments (with the exception of an area that extends from Tar Al Rowak to Ansab police station) and phosphatic siliceous limestone and dolostone.
- At some localities it is marked by the presence of (2-3 meters) of thickness of red to pink papery claystone.

In different parts of the western and the southern desert, the Zahra formation overlies with angular unconformity the upper shelly unit of Umm Er Radhuma formation. The contact is marked by thick red gypsiferous claystone in the west and the south areas of Al Nukhaib town, Whereas further to the south near to the Saudi Arabia-Iraqi borders and at Al Salman area, the contact is marked by conglomerate and pebbly sandstones. In subsurface section of the boreholes (KH.5) at Salhobiya, (KH.2) at Umm El Hashim and (KH.8) at Wadi Ghanimi, the formation is overlain by Rus formation conformably. In Abu Radham, Salman, Takhadid and Schibacha boreholes, the formation is overlain by the lower member of

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Dammam formation (Jil formation) (Jassim et.al.,1984) and (Tamer Agha,1984). The contact between Umm Er Radhuma formation and Dammam formation is exposed in wadi Tabbel near Shithatha.

Figures (5),(6),(7),(8) and (9) show the keyholes and oil wells that were used to determine the thickness and the extension of Umm Er Radhuma formation and the Stratigraphical position with other formations.

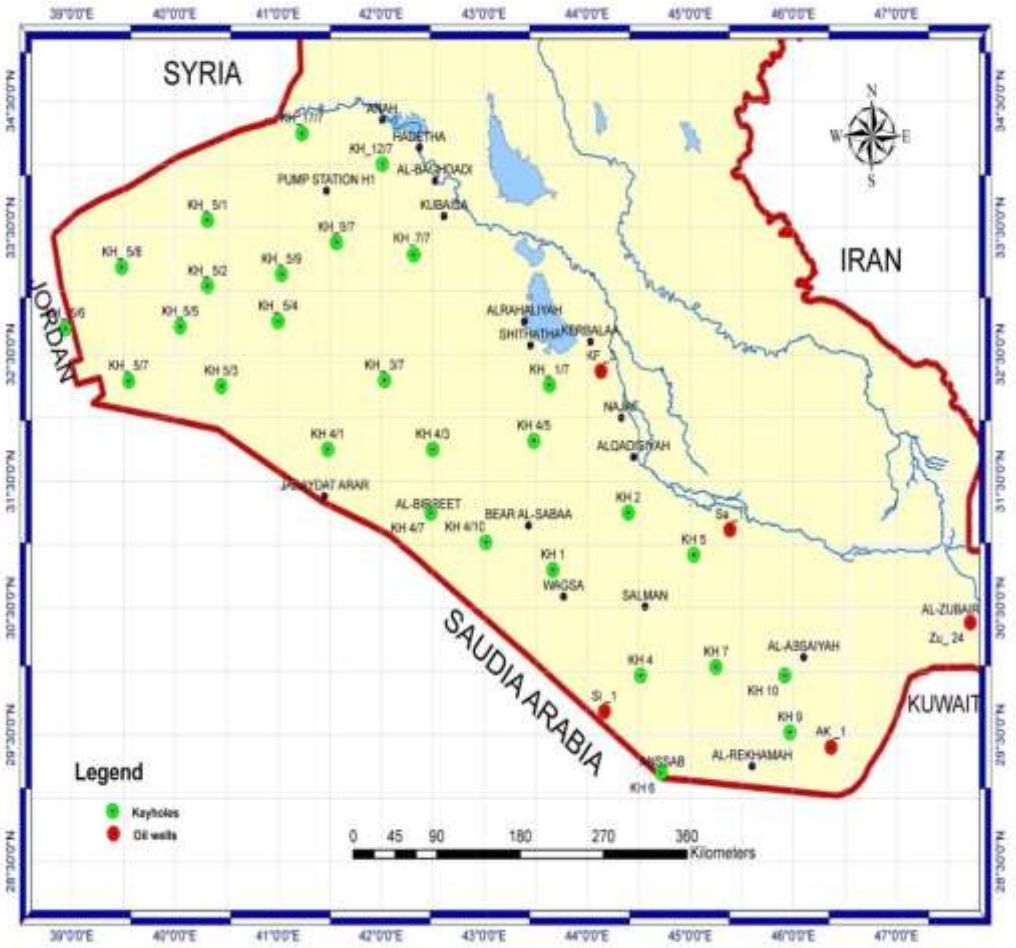

Figure (5) show the locations of the keyholes in the studied area

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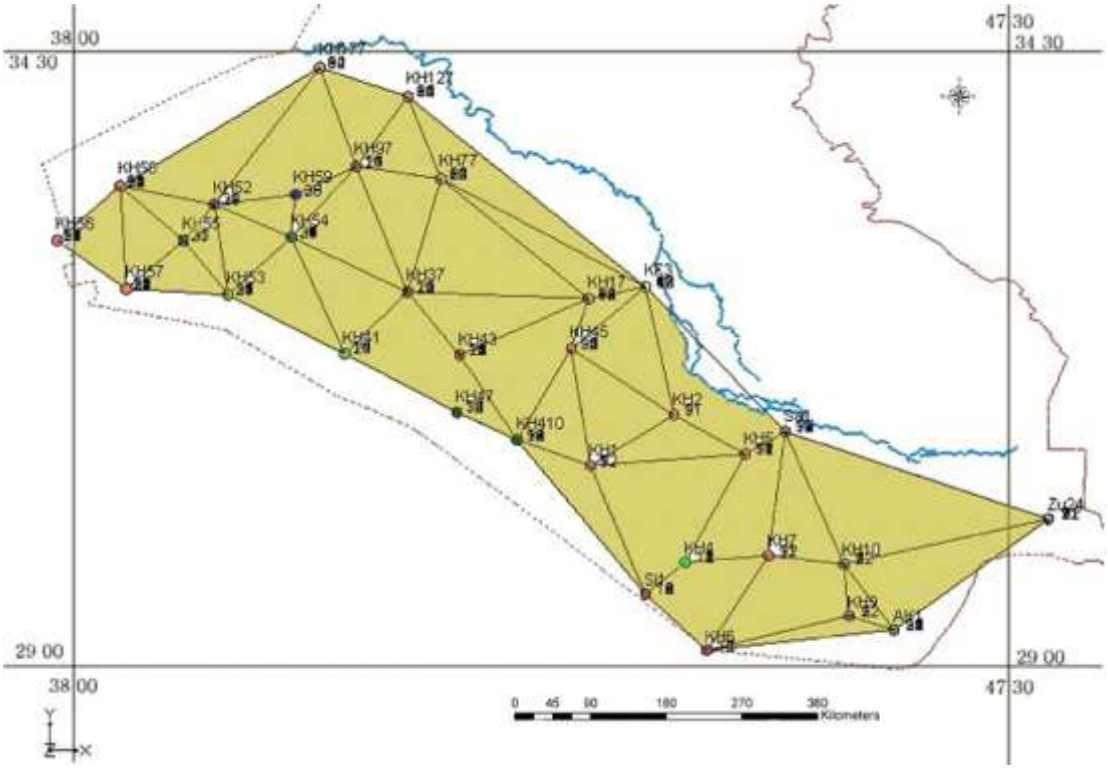
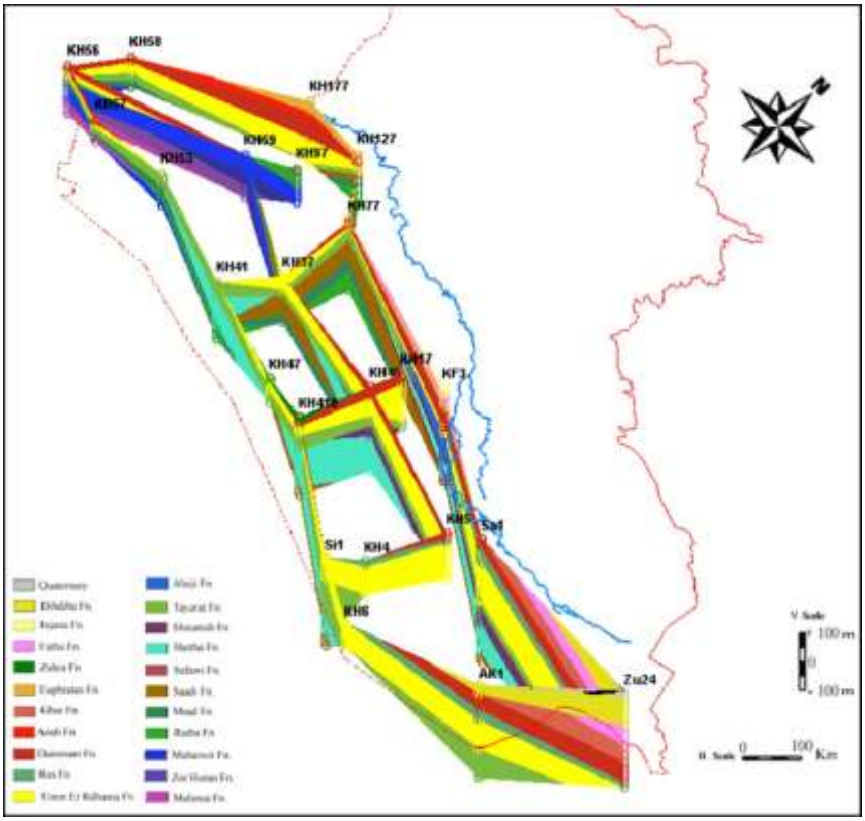


Figure (6) shows the trend of the sections between the keyholes in the studied area



Figures (7) The stratigraphic correlation between the wells in the studied area (processing GMS V.6)

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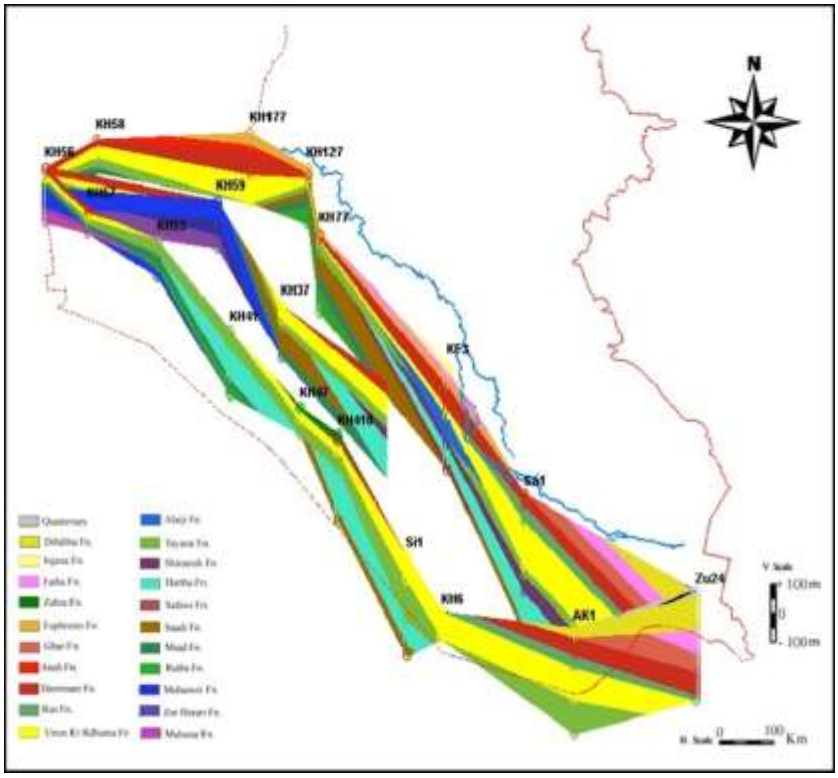
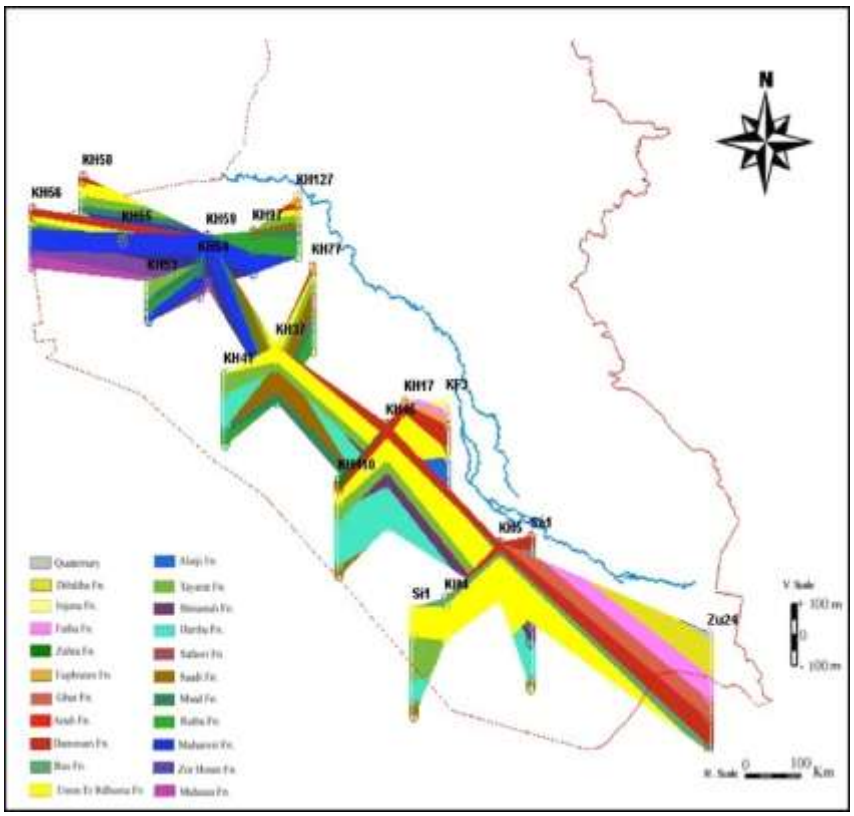


Figures (8) The stratigraphic correlation between the wells in the studied area (processing GMS V.6)



Figures (9) The stratigraphic correlation between the wells in the studied area (processing GMS V.6)

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Hydrogeology of Umm Er Radhuma aquifer:

Umm Er Radhuma formation is characterized by a wide extension in the northern and southern deserts; furthermore its extension covers most parts of the northern desert excluding Rutba uplift. It is divided into two aquifer types: confined and unconfined. The confined aquifer is normally found in the eastern and the northeastern parts of the northern desert and most parts of the southern desert, while the unconfined aquifer found in the west of the northern desert and the west and southwestern parts of the southern desert near the Iraqi-Saudi Arabia borders. The importance of studying this formation and specifying its hydrogeology is due to the fact that:

- It is exposed to the surface or lies close to it, allowing easy penetration by wells. - Possible evaluation of the natural recharges of the aquifer .
- Groundwater quality is relatively good compared to other aquifers in this region. It can be used for agriculture in large areas of the western desert.

The natural properties of Umm Er Radhuma aquifer:

The characteristics of any aquifer are affected by the nature of its rocks. Limestone rocks have a great importance in the studied area since they have wide extents and large thickness. Their depositional nature has been reflected in the nature of the aquifers they form. Limestone beds in the studied area are distinguished by the presence of cracks and joints structures in addition to the widespread phenomenon of cavities (Idrotecneco, 1977).

Cracks and sinkholes are used as corridors to infiltrate surface water inside the aquifer. Infiltrated water moves as well through the levels of stratification in the aquifer assisted by the expansion in these levels because of the ability of water to dissolve limestone (Fetter,1980).

The viability of soluble limestone under the influence of surface water leads to the creation of channels under the surface where water moves toward the groundwater in the aquifer (Tyracek and Youbert,1975).

On this basis, aquifers which are composed of limestone rocks are non homogeneous due to the presence of joints , cracks and channels under the surface, reflected in the variable values of their permeability from one site to another (Fetter,1980).

Boundary conditions of Umm Er Radhuma aquifer:

The total area of the formation is about 151,834 km^2, the most important of it is around Rutba uplift and parallel to the Iraqi-Saudi Arabia borders.

Umm Er Radhuma formation contains two types of aquifers: The first one is an unconfined aquifer that covers an area of (60,068) km^2, while the second is a confined aquifer that covers an area of (91,766) km^2.

The boundary of the unconfined aquifer lies toward Rutba uplift. The formation in the same uplift is considered as a dry aquifer and its boundaries are changeable due to the recharge which may result from precipitation. It is located to the east of Rutba uplift since the outcrops of the formation which are exposed at the uplift itself do not form an aquifer. To the west of the uplift and towards the Jordanian borders, the formation has a limited exposure and is totally dry inside Iraq. Figure (10) shows the extents of both the unconfined and confined aquifers in Umm Er Radhuma formation where it could be noted that along the national borders at the southern desert the aquifer is usually unconfined.

The exposed surface of the formation and the extent of its unconfined aquifer represent all the recharge areas of the aquifer. Umm Er Radhuma unconfined aquifer changes to a confined one when flowing eastwards toward Euphrates river in areas that extend in the northern desert in Husaybah, through Ana and Heat reaching Bahr Al-Najaf. It constitutes, with Dammam aquifer which lies above it, an aquifer system with possible hydraulic connection between the two

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aquifers. The piezometric pressure is equal in the two aquifers in these regions when measured in wells penetrating them both. This connection is not observed between these two aquifers in the southern desert due to the presence of the impearmeable evaporate and marl beds of Rus formation which separate the two aquifers from each other (Al Jawad,et.al.,2001).

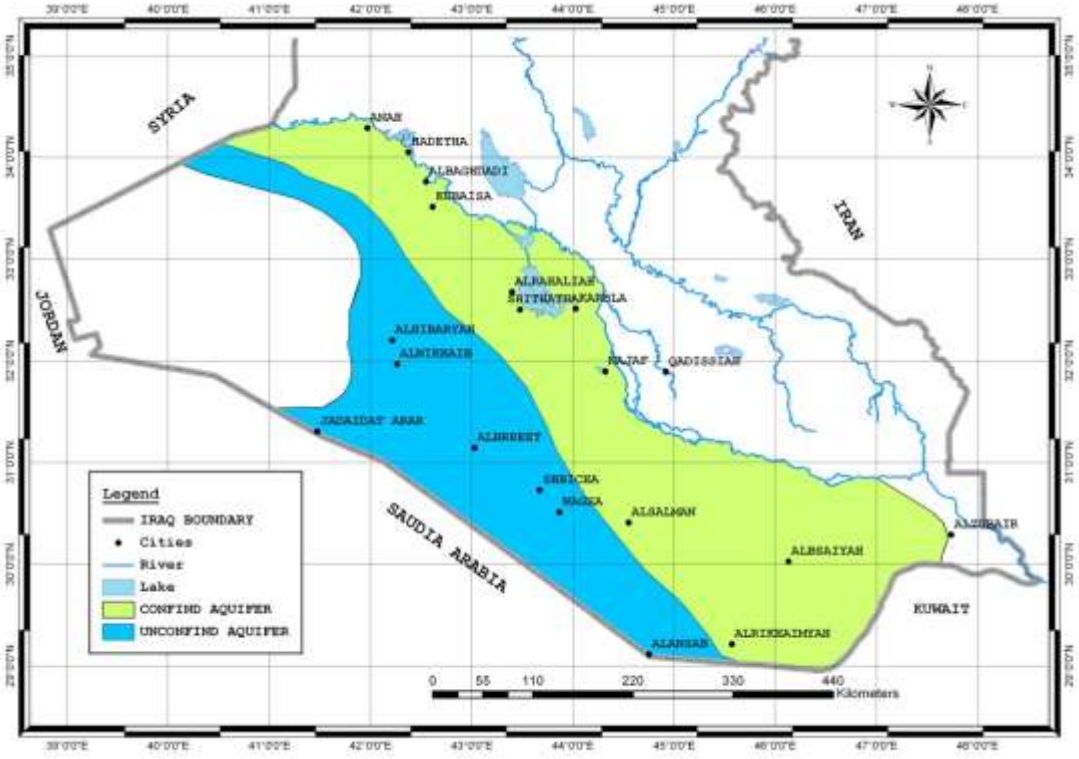

Figure (10) Extents of the two types of aquifers inUmm Er Radhuma formation

Groundwater movement and recharge:

Rainfall is considered as the most important source of groundwater recharge. In spite of the prevailing arid desert climate in the studied area, the low rainfall occurrences are described as heavy and intermittent leading to occasional flow events that may cause floods in valleys and depressions. In the south, the southwest and the west of the studied area, flood water contributes to groundwater recharge by deep underground percolation through faults and fractures to recharge the deep confined aquifer. For the unconfined aquifer, rain water infiltrates downward through the formation outcrops. In general Umm Er Radhuma aquifer is recharged from rainfall by the above two methods (Al-Jawad and Khalail, 2001). Umm Er Radhuma Formation, is also, recharged by subsurface flow of the upcoming water of the aquifer in Saudi Arabia entering the basin from the south, the south- west and the west margins of the region through faults and subsurface channels. Umm Er Radhuma formation wide exposures facilitate the recharge process from rain and surface runoff water, specially, in the south and the southwestern parts of the area. The recharge is effectively through the faults and subsurface channels. The source of this recharge is the regional extends of the aquifer in Saudi Arabia territories along its borders with Iraq (Al-Jawad and Khalail, 2001).

Groundwater either discharges in form of springs or flows underground into Mesopotamian Plain sediments. Locally, deviations from the main groundwater direction may occur due to geological, structural and topographic nature of the area, which effect groundwater movement. The regional trend of groundwater movement in the western desert is generally towards the east and the northeast. But, locally, the flow of groundwater takes different

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directions throughout the region depending on geological, topographic and structural features, Figure (11).

Generally, groundwater movement in the southern desert is from the southwest to the northeast and southeast, towards the discharge zone along Euphrates river, Hor Al-Hammar and Shatt Al Arab (Al-Jiburi andAl-Basrawi, 2009).

Groundwater flow pattern in Umm Er Radhuma aquifer is affected mainly by the permeability and the fractured density of the rock units that contain groundwater and by the hydraulic gradient.

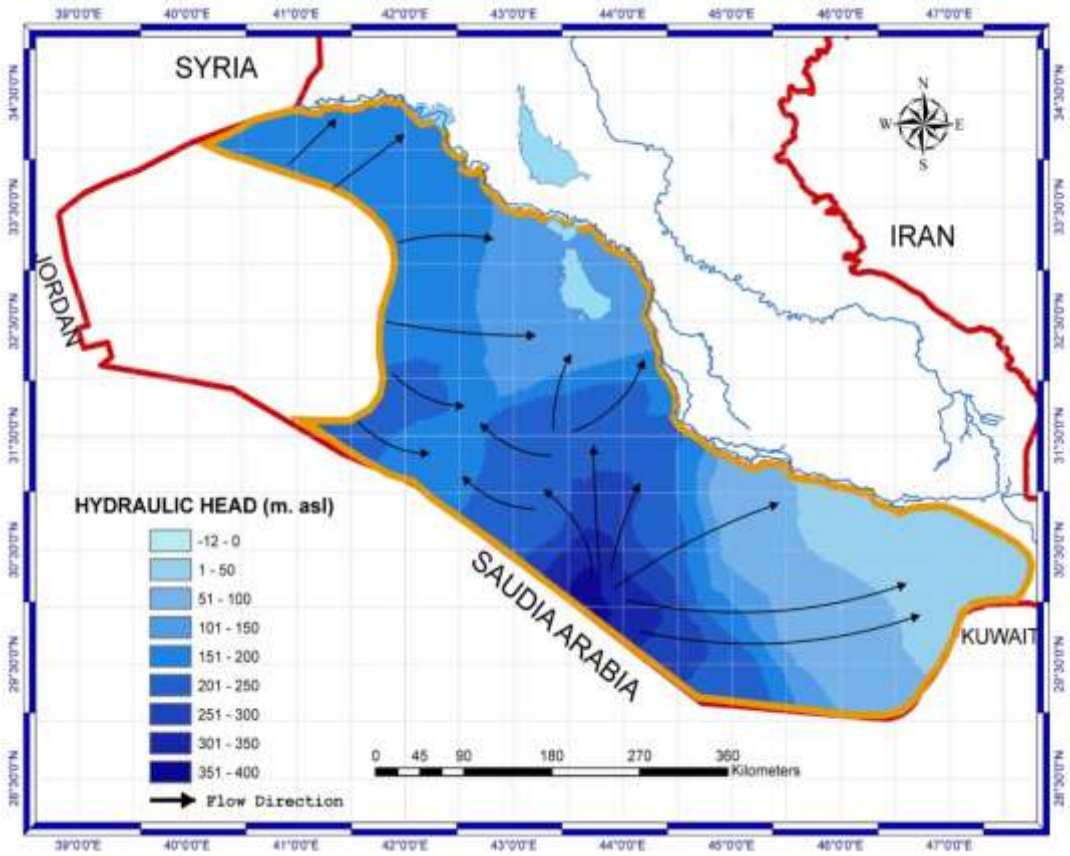

Figure (11) Groundwater movement of Umm Er Radhuma aquifer

This movement is distinguished in the recharge areas and it is towards the east, and also the lateral movement from the recharge zone in the west to the discharging zone in the east according to the hydraulic gradient from the west and the southwest towards the east and the northeast. In addition to the lateral movement of groundwater in Umm Er Radhuma aquifer, there is a vertical leakage of groundwater from Umm Er Radhuma to Dammam aquifer which lies above it. The hydraulic relationship between Umm Er Radhuma and Dammam aquifers is of two directions. Such hydraulic exchange exists in zones to the west of Al Razzaza lake and in Bahr Al Najaf zone (Al-Jawad and Khalail, 2001).

The vertical leakage between the two aquifers is attributed to the hydraulic head difference that arises between them. When Umm Er Radhuma aquifer posses higher piezometric head than Dammam aquifer, an upward water movement is generated resulting in a natural and artificial discharging from the upper aquifer. The artificial discharge is due to pumping which plays a significant role on the direction and velocity of groundwater flow.

The hydraulic properties of Umm Er Radhuma aquifer:

The hydraulic state of Umm Er Radhuma aquifer changes specially in accordance with its boundary conditions, its hydraulic properties which changes from one location to another, the

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stratification of its formation which consists mainly of layers of limestone and dolomite that are normally dissolved by solution processes , its structural setting , and finally due to some erosion factors. These factors affect the porosity and the density of fractures which are reflected on the hydraulic properties of the aquifer expressed in terms of its transmissivity and storage coefficient.

The transmissivity value of Umm Er Radhuma varies between (3-2100) m^2/day reflecting a highly heterogeneous aquifer due to the variations in the density of its fractures and the porosity of its rocks. Generally, low transmissivity values are exhibited in the southern desert wells, more specifically in wells Hasab w4/8-1, Al-Zarga 2 and in Al Saadiya 2, while the highest values are found the northern desert wells at Baraisa and Habariya.

The storage coefficient values for the confined aquifer may attain a value of (1.2×10^{-4}) in well KH12/7, while in Takhadid the value of the specific yield is (2.45×10^{-2}) for the unconfined aquifer,(Al Jawad,et.al, 2001).

Groundwater stored volume in Umm Er Radhuma aquifer:

The static volume of the aquifer:

The static volume of groundwater in Umm Er Radhuma aquifer can be calculated in three stages:

- The first stage is to calculate the storage of the unconfined aquifer in Umm Er Radhuma using the volume of the aquifer and its specific yield value which was determined for wells penetrating only the unconfined aquifer.
- The second stage is to calculate the confined storage in the confined aquifer using the storage coefficient of the aquifer and its peizometric head observed above the top of the aquifer.
- The third stage is to calculate the storage in the confined part of the aquifer when it finally becomes unconfined due to the extractions causing aquifer head to attain a level lower than its top.

The results of these calculations are shown in table (1) indicating that Umm Er Radhuma aquifer static resources may reach to (275.464915) billion cubic meters.

Renewable resources:

Depending on this study, a rate of only (5%) of the annual rainfall finds its way to recharge Umm Er Radhuma aquifer through its exposed formation at its surface. The annual rainfall in the desert has an average of (107.7) mm, while the exposed area of the formation in some parts of the northern and the southern deserts can receive infiltrated rain water through cracks and fractures reaches to $(60{,}068 \times 10^9)$ m^2, using these figures, the natural recharge rate value of Umm Er Radhuma aquifer is in the order of $(38023 \times 10^4$ m^3/year) million m^3 / year.

Table (1) Groundwater storage in the Umm Er Radhuma aquifer

State of Aquifer	Area 10^9 m^2	Storage coefficient for confined %)(	specific yield for Aquifer (%)	the peizometric pressure (m)	the volume of the aquifer 10^9 m^3	The Storage of aquifer 10^9 m^3	The Storage of confined aquifer 10^9 m^3	The total storage 10^9 m^3
unconfined	60.068	-	2.45×10^{-2}	-	5028	123.196535	-	123.196535
confined	91.766	1.2×10^{-4}	6.0×10^{-3}	96	25202	151.212	1.056384	152.26838
								275.464915

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