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## Wells location effect on the underground gas storage in UM ERadhuma Formation-Ratawie oil field.

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**Abstract.** The aim of this study is to investigate the feasibility of underground gas storage in UM ERadhuma formation /Ratawie oil field. This formation is high permeability bed according to the available coring data, dolomite, and water bearing and located below RUS formation which consists of impermeable anhydrite beds. Interactive petrophysics (IP), Petrel RE and Eclipse 100 softwares are used for well log interpretation, conducting a reservoir simulation model and predicting the reservoir behaviour during storage respectively. A black oil, three dimensional and two phase fluid model has been used. The results showed that upper reservoir of UM ERadhuma formation is good for underground gas storage because of the tightness, of its cap rock and its properties for storing gas. It has been found that the available volume for storage is 14.3 billion cubic feet with a structural closure of 45 m. moreover, two groups of suggested injection wells location are used during this study to investigate the effect of wells location on the injection behaviour and it has been found that high space wells location is more suitable for the gas injection.

### 1. Introduction

Natural gas is playing an important role in meeting the world's energy demand because of the clean burning and its huge energy. According to the International Energy Agency, in the next twenty years, the average growth of natural gas demand is expected to be over 1.8% per year. Also, there is no doubt that natural gas has a changeable demands according to the months of the year, whether they are cold or hot. [1]

Natural gas storage is used to face the expected future peak demand, maintain the balance between supply and demand and to save the non-invested gas from burning and losing[1].

Large volumes of natural gas don't invested and lost by burning in Iraq because the main type of natural gas is the associated gas and needs high capitals of money to be invested [2]. For example, more than 1.5MMMSCF/D were burned in 2016 which means, 7500 ton of liquefied gas, 1.2 MMMSCF of dry gas and 1650 ton of benzene have been lost[2]. Therefore; a new technique for gas storage must be used. In fact, underground gas storage is not very modern but it is highly used by many countries in the world such as Europe, US and Russia [3].



## 2. Methodology

In current study, two phase and 3D black oil reservoir simulation model have been conducted to present the aquifer behavior during the injection processes. Therefore; Petrel RE and Eclipse softwares have been used to build the reservoir model. The four main stages that have been conducted during this study were:

### 2.1 Static geological model

Static geological model is very important in reservoir description and represents the beginning for dynamic fluid model preparation. Therefore, during this study a geological model for RUS and UM ERadhuma formation have been built by using Petrel RE software and depending on well logs, core data, well heads and tops of 7 wells of Ratawie field which were; RT-3, 6, 7, 8, 9, 10 and 11.

### 2.2 Dynamic fluid model

Dynamic fluid model is important to predict the reservoir behavior with time under any process such as; production, injection, stimulation, etc..... Therefore, a black oil 3D dynamic fluid model has been built for RUS and UM ERadhuma formations to investigate their behavior during the injection process.

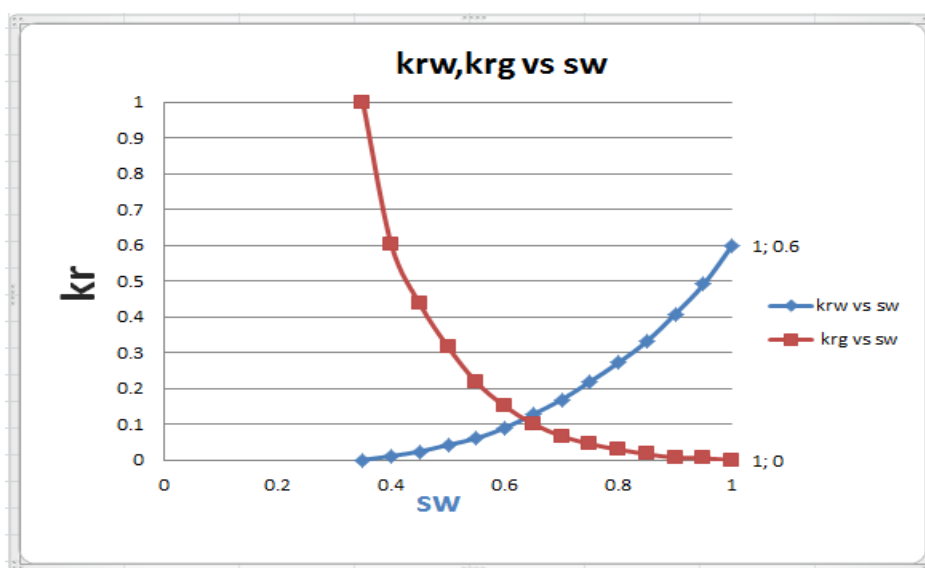
Dynamic model have been built depending on the static geological model, initial reservoir properties (**Table 1**), relative permeability data [4], capillary pressure data [4], formation water properties [5] (**Table 2**) and injected gas properties [6] that has been used for injection was from zubair oil field because its data was available. Figure 1, 2 and 3 represent the relative permeability data, capillary pressure data and the injected gas properties respectively.

**Table 1:- initial reservoir properties.**

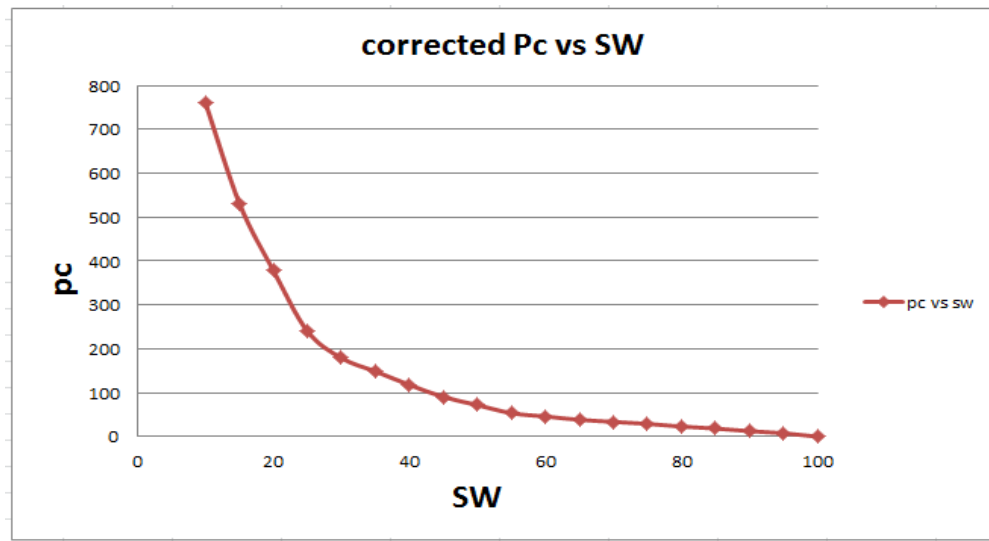
Reservoir pressure	Datum depth (ft)	Water contact(ft)	T (F°)
1450 psi	-3000	-2000	110

**Table 2: - formation water properties [5].**

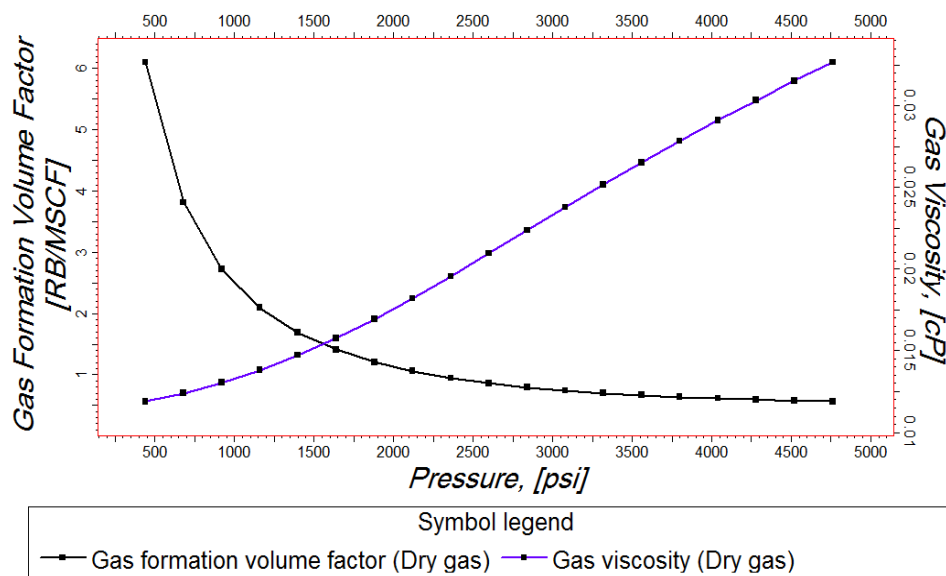
Water density(lb/ft <sup>3</sup> )	Comp. 1/psi	BW (RB/STB)
67.549	$2.4 \times 10^{-5}$	1.0003



**Figure.1:- relative permeability of gas and water for UM ERadhuma formation. [4]**



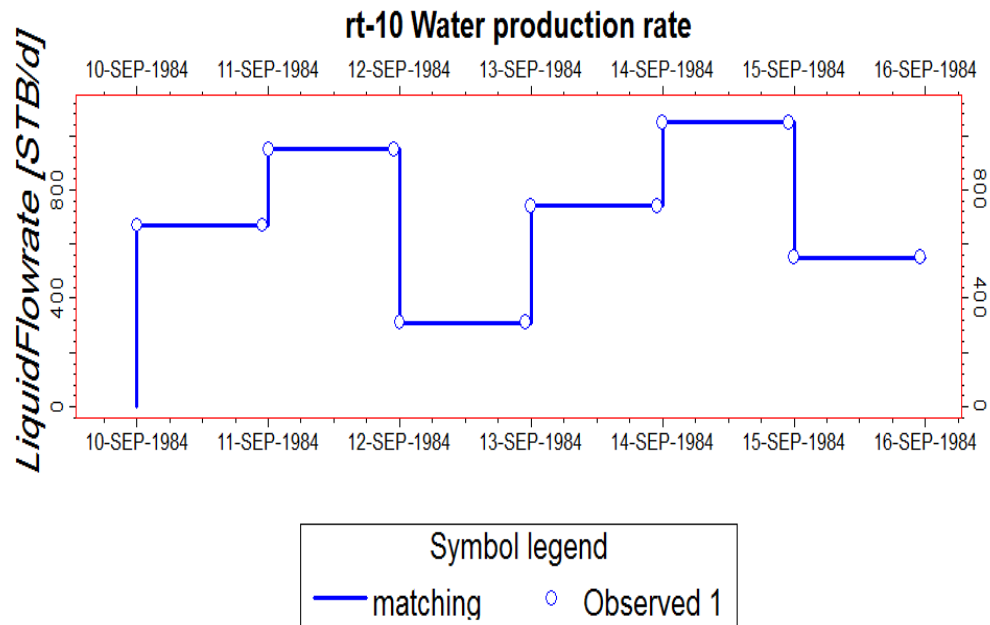
**Figure. 2:-** capillary pressure curve for UM ERadhuma formation. [4]



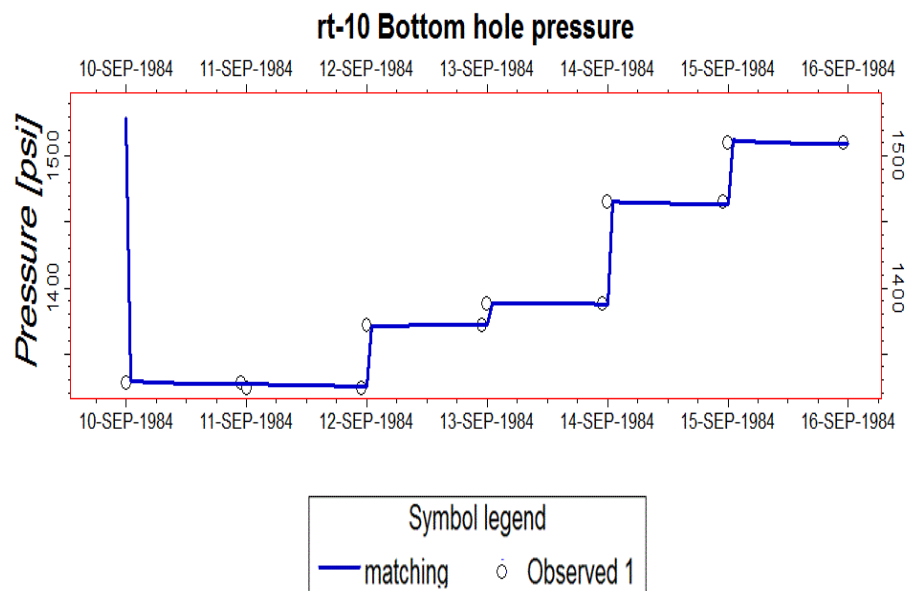
**Figure.3:-** injected gas properties. [6]

### 2.3 History matching

History matching is essential to insure that the constructed model represents the reservoir. Because of UM ERadhuma formation is an aquifer and located at shallow depth (800-850 M), no production data are available. However, history matching in this study was depending on 6 days DST tests which are conducted on the well RT-10 in 1984. Figure 4 and 5 represent the obtained history matching of the well RT-10 for water production rate and bottom hole pressure respectively.



**Figure.4:** Water production rate history matching of well RT-10.



**Figure.5:-** Bottom hole pressure history matching of well RT-10.

## 2.4 Prediction of reservoir behaviour during the injection process

In order to predict the reservoir behavior during the injection process, 9 wells have been assumed to be drilled in two groups of wells location (A and B) in addition to the wells RT-8 and RT-10 to use them for the gas injection. These two groups are different in wells location (high spacing and small spacing). Furthermore, the choice of the location is depended on the permeability distribution. Simulation injection period was of 10 years of injection with a perforation interval of 19 m and constant bottom hole pressure (BHP) of 1600 psi which is less than fracture pressure of 1800 psi. Figure 6 and 7 represent the wells location of group A and B respectively.

## 3. Results

### 3.1 Available storage volume

Volumetric calculation have been conducted on the geological model to find the total pore volume according to the structural closure which is 45 m. Figure.8 shows the 3D porosity distribution of the upper reservoir unit and its cap rock. However, the result showed that the total pore volume of the structural closure of upper reservoir of UM ERadhuma formation is 22 billion cubic feet. Additionally the available storage volume is equal to 14.3 billion cubic feet which is calculated by using the following equation.

$$\text{Available volume} = \text{total pore volume of the closure area} * (1 - \text{swc})$$

Where:-

Swc: - connate water saturation which is equal to 0.35 according to the relative permeability data.

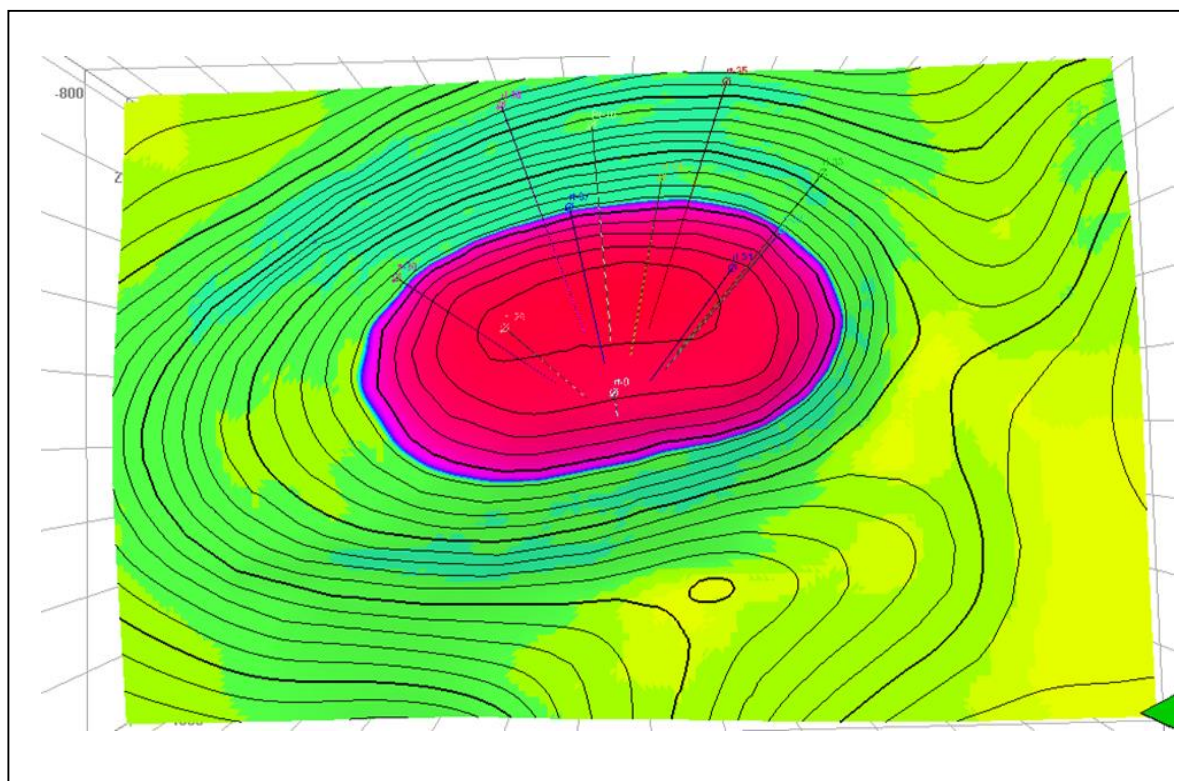
### 3.2 Effect of injection wells location

Two cases have been conducted on the upper reservoir during this step with two different 11 wells locations (group A and B) as shown in Fig.6 and Fig.7 at constant BHP of 1600 psi, perforation interval of 19 m and injection period of 10 years. The injection processes were without injection rate target and without water withdrawal to put the reservoir under high pressure in order to check the cap rock capability to reserve the gas and prevent it from upward movement

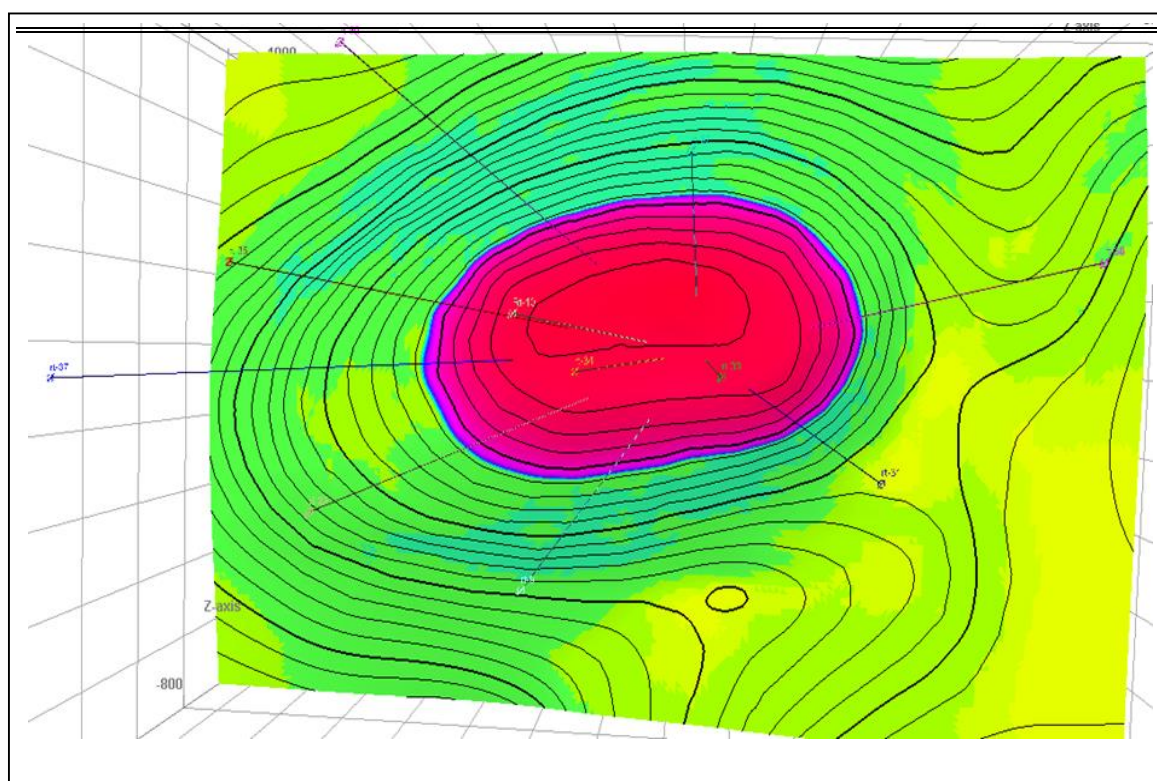
The values of BHP have been selected less than the fracture pressure of the cap rock of the upper reservoir which is about 1800 psi. Figure.9 and 10 show the resulted curves of cumulative gas injection, average formation pressure and gas injection rate of the mentioned two cases.

The results showed that there is a high effect of wells location on cumulative injected gas. However, cumulative injected gas was equal to 144.1 MMMSCF at group A wells location and equal to 182.8 MMMSCF at group B wells location because the small space between wells has an effect on the reservoir pressure and pressure interference may occur.

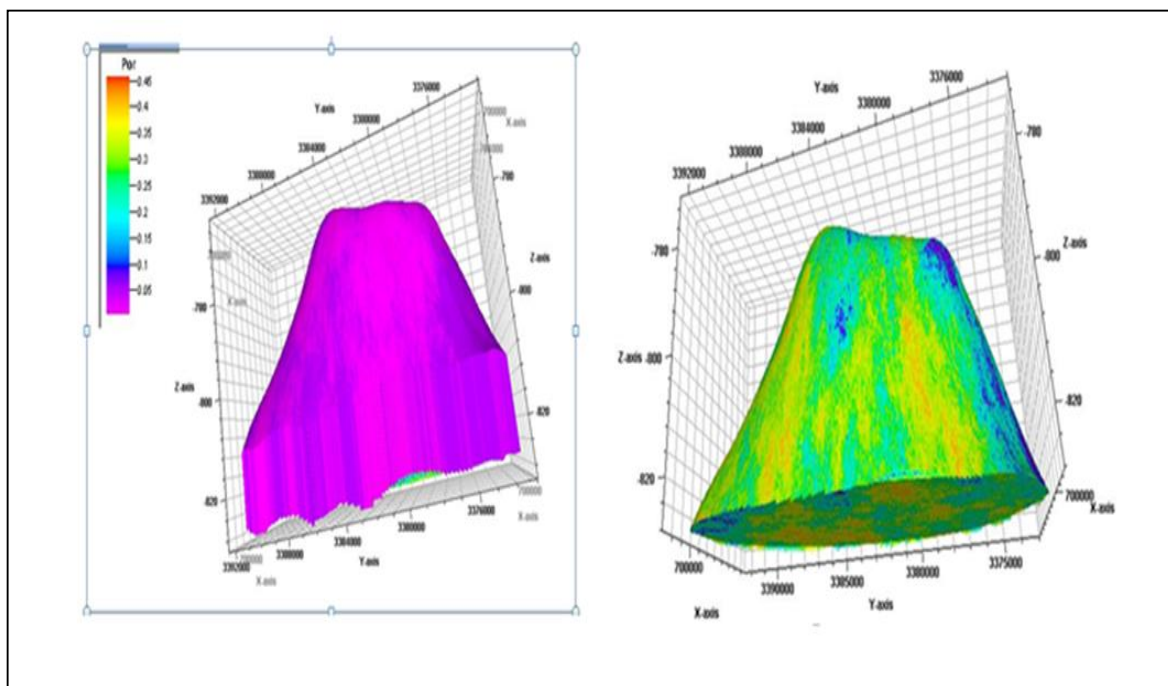




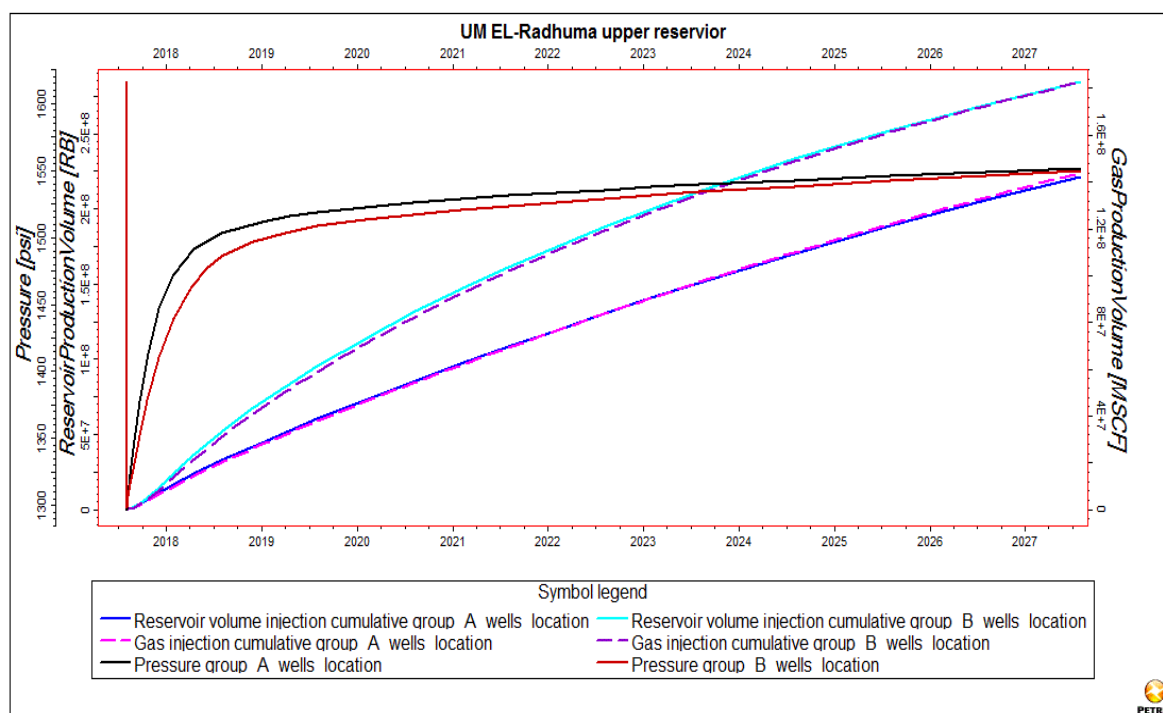
**Figure.6** : - Group A wells location.



**Figure.7** : - Group B wells location.

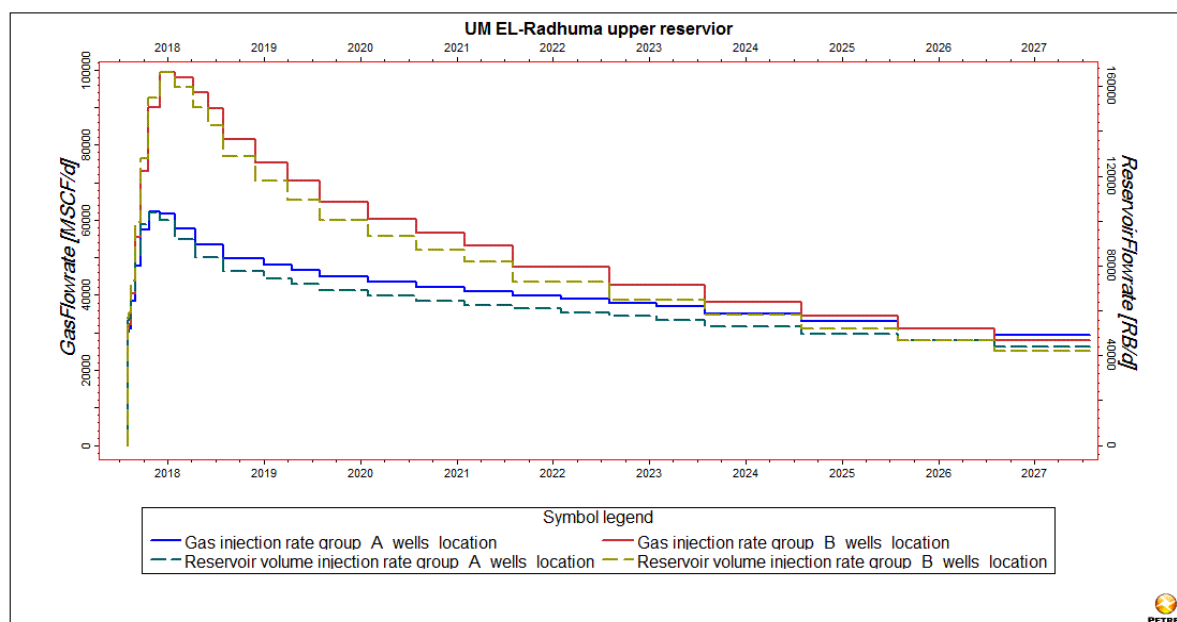


**Figure.8:-** porosity distribution of the closure area of UM ERadhuma upper reservoir and its cap rock.



**Figure.9 :** - Effect of wells location on average reservoir pressure and injected gas cumulative during 10 years of injection.





**Figure.10 :** - Effect of wells location on gas injection rate during 10 years

#### 4. Discussion

During this study, upper reservoir of um ERadhuma formation has been tested for underground gas storage using two wells location groups and find the effect of wells location on cumulative gas injection and reservoir formation pressure during 10 years injection period.

Regarding the injection wells location effect, it can be noticed that injection wells location have a good effect on the cumulative gas injection and formation pressure because of well location effect on formation pressure distribution and an interference between wells will be occurred which has an effect on the differential pressure between bottom hole pressure and formation pressure, therefore; changing in well location from small well spacing (group A) to a high well spacing (group B) between injection wells leads to a high increment in cumulative gas injection because it effects on the reservoir pressure. As noticed in the injection rate curve (**Figure.10**), injection rate is changing during 10 years period. This change in gas injection rate is due to the increase in formation pressure which leads to a decrease in differential pressure value. Therefore; in order to decrease the increment in formation pressure during the injection, pressure relief is recommended which is done either by water withdrawal from the bottom of the reservoir or by making a shut in period between injection periods.

From gas saturation distribution of UM ERadhuma formation and its cap rock (**Figure.8**), it has been noticed that gas saturation in the cap rock and all the remaining upper part of RUS formation is equal to zero which means that there is no gas escaped above the cap rock which implies that RUS formation is good cap rock and UM ERadhuma is suitable for underground storage purposes.

## 5. Conclusions

- 1- Upper reservoir of UM ERadhuma formation is suitable for underground storage because of the tightness of RUS formation that overlying it.
- 2- High volume for storage is available in UM ERadhuma formation which is equal to 14.3 billion of reservoir cubic feet.
- 3- The location of gas injection wells is very effective on gas injection rate and cumulative injected gas because it has an effect on pressure distribution. High spacing between injection wells (group B) gave a good result and high cumulative gas injection which is 182.8 MMM (billions of surface cubic feet).

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