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Looking at the Big picture: Reclassifying water disposal wells into injectors to safeguard field reserves and future potential

Jihad Al-Joumaa [1, *]

[1] Oil and Gas Engineering Department, University of Technology-Iraq, Baghdad-Iraq

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Corresponding Author:
Jihad Al-Joumaa
150078@uotechnology.edu.iq

Abstract

The Deep Water Disposal project was initiated in 1995 with the aim of managing excess water output from the primary facility. The injection into a shared deep formation has resulted in a significant boost to the pressure in nearby fields. This effect can be observed through pressure measurements, which demonstrate that the field was in a state of depletion before the commencement of water disposal. However, the pressure stabilized once stable disposal rates were established. Recently, a decline in nearby fields' pressure has been noticed in response to lower disposal rates. The objective of this study is to evaluate the level of pressure support in adjacent areas resulting from the volume of waste disposal and establish the necessary disposal rate needed to sustain the desired pressures. Ultimately, the goal is to reclassify the relevant portion of deep-water disposal volume as proper water injection, to avoid any unnecessary decommissioning of the disposal wells and hence losing this energy source to the reservoir. This Novel approach of mixing operational and reservoir data deals directly with the topic of voidage replacement, pressure decline, reservoir behavior, impact of deep water disposal and water injection of performance, and conducting simple forecasting methodology that is fit for purpose to come up with practical results to be directly applied in a real life situation.

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1. Introduction

water produced in conjunction with oil and gas can be safely and effectively disposed of by injecting it into subsurface zones using disposal wells. Usually, the underground layer is not an oil and gas-producing one. The disposal interval may, on occasion, be a productive zone where oil or natural gas has been or is presently being produced. In any scenario, impermeable rock layers must completely surround the disposal interval on all sides. However, this might not be the case at all times depending on geological layer availability. For the goal of improving oil recovery from a reservoir, injection wells introduce fluids into the reservoir[1].

In general in some areas, injection wells make up the great bulk of wells. Water brought to the surface during the production of oil and gas wells is dealt with using a water disposal system. This water frequently contains a large number of contaminants that cannot be safely disposed of at the surface. Wells and caverns for water disposal provide a reliable and secure alternative to get rid of this waste water[2].

Any producer of hydrocarbons where water is present must have a method for handling the produced water. Water can be recycled and used again in a variety of ways, such as hydraulic fracturing and water floods, however a lot of this water is unusable and needs to be disposed of. Some operators have a high requirement for water disposal. Frac flow-back and produced water are two major waste products created by production operations. Although some of this water can be recycled, the most of it will be disposed of[3].

To inject fluid underground into porous geologic formations, a water injection well is employed. These subterranean structures might be anything from a modest soil layer to thick sandstone or limestone. Water, wastewater, brine (salt water), and water that has been combined with chemicals are all examples of injected fluids.

Injection wells are used by operators to sweep additional oil toward producing wells and to raise or sustain pressure in an oil field that has been exhausted by oil production. Waterflooding is a term that is occasionally used to describe this kind of secondary recovery[4].

In principle, there isn’t any design difference between a water injection well and a water disposal well, but the difference is sometimes is in the injected fluid quality, where water injection wells tend to have a relatively better water quality compared to disposal wells where the water quality is lesser, however that is not a determining reason for distinguishing between water injectors and water disposal wells.

Generally speaking, repurposing water disposal wells to water injectors is possible and only requires administrative changes and few additional surface requirements[5] which will not be discussed here, impact on subsurface and reservoir pressure support will be the key area of discussion in this paper.

The primary objective of waterflooding an oil reservoir is to increase oil recovery and production rates. "Voidage replacement" is the injection of water into the reservoir to bring the pressure back to its initial level and keep it there. Oil is moved out of the pore spaces by the water, but how much oil is moved depends on a lot of different things (like the viscosity of the oil and the characteristics of the rock)[6].

A well usually produced saline water or brine in addition to oil, and as the oil production rate decreased, the water production rate frequently increased. Usually, this water was dumped into surrounding streams or rivers as a kind of waste disposal. Reinjecting generated water into porous and permeable subsurface formations, including the reservoir interval where the oil and water originally came from, was first practiced in the 1920s. Reinjection of generated water into an oilfield was widely used by the 1930s[7].

Waterflooding became an efficient way to increase oil field recovery due to a number of variables, including the necessity to dispose of the saline water that was produced along with the oil. Early on, it was realized that due to the depletion of the reservoirs' natural energy, only a small portion of the original oil in place (OOIP) was typically recovered during the primary-production period. The enormous amount of oil that remained required to be produced using further recovery techniques[8]. Waterflooding was the logical next step after primary production to recover extra oil from reservoirs whose oil production rate had decreased to extremely low levels due to water injection's early success in extending the oil-production period by years.

Some important elements that influenced the development of water injection are[5]

• Water is affordable.

• Streams, rivers, and oceans close by are typically readily accessible sources of vast amounts of water, as are wells drilled into shallower or deeper subterranean aquifers.

• large amounts of water are typically produced from the subsurface anyways, so recycling comes into play

• The increased reservoir pressure caused by water injection caused producing wells close to the injection wells to flow or pump more quickly.

At the same time, the scientific explanations for the effectiveness of waterflooding were discovered (i.e., that water has viscosity, density, and wetting properties, compared to oil, that affect how efficiently it will displace various oils from reservoir rock)[9].

A large number of onshore oil fields globally were producing using this technology in various well-pattern configurations by the 1970s, for which waterflooding was the obvious recovery process. The owners and operators of several offshore oil fields throughout the world decided that water injection was necessary. Since then, numerous large-scale water-injection projects have been used to treat oil reserves in a variety of places, including the Arctic, the North Sea, arid regions, and far offshore[10].

Our case study concerns 4 oil fields, namely A, B, G & E fields, which are middle eastern oil fields with clastic reservoirs as the primary producing formation. All those fields have a common deep aquifer formation, where all of them connect, but all have a separate hydrocarbon accumulation.

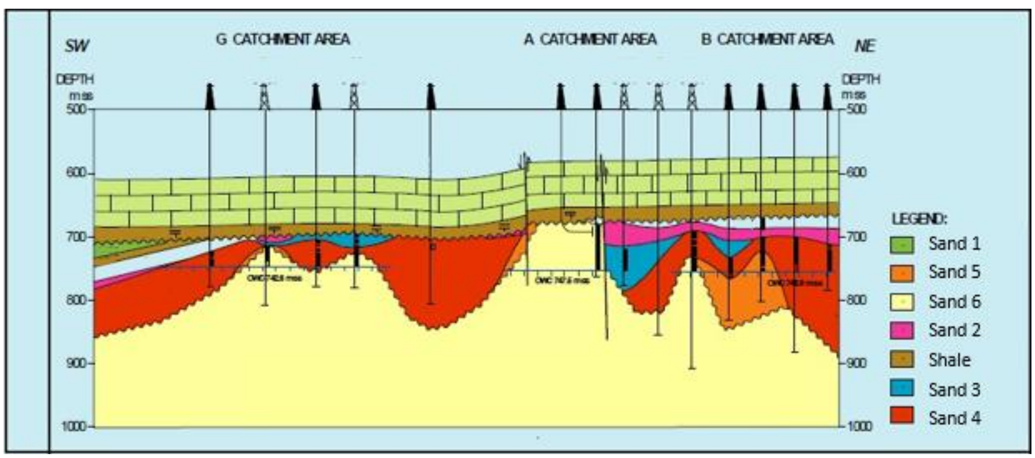

Figure 1: G, A and B fields cross section showcasing the common formations and sands connection

The perimeter of one of those fields, namely the G field, has an active Deep Water Disposal constellation of wells which are injecting continuously into the deeper Sand 6 formation[10], the approximate distance to the field from those disposal wells are around 2.5 km. Field G, which is situated closest to the water disposal sites, has experienced a significant response and alteration in pressure behavior since the commencement of those operations

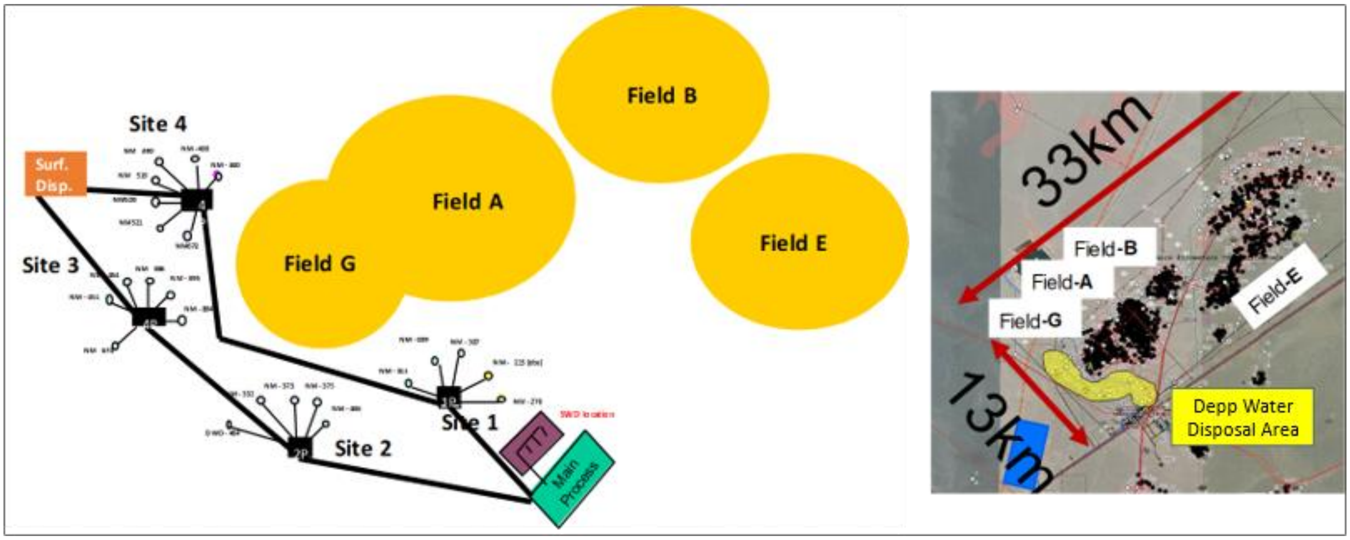

Figure 2: Deep Water Disposal sites and the Approximate Location to nearby fields in question

Majority of the re-injected water into the disposal sites comes from those fields, with a minority coming from other fields that produce into the same production facility as those.

Water disposal activities commenced at Site-1 in the mid-1995s and additional sites were gradually added to increase the water disposal capacity due to the increased volume of water generated from the processing station over time. Site-4, with seven wells, was introduced by the end of 2004 to further enhance the disposal capabilities.

The initial plan for the deep water disposal was to divert all the water to a surface disposal site e.g. evaporation ponds or shallow disposal wells by 2029 and decommission all the deep disposal wells to save energy and operations cost. However, with developing knowledge of impact of nearby fields, it has been advised against going ahead with this operation, and instead, safeguard some of these wells to supplement the pressure support of the nearby wells[6].

The primary objective of reclassifying the deep water disposal wells as water injectors is to guarantee the preservation (if not enhancement) of their share over time, while acknowledging their role as a source of pressure support rather than merely "disposal" wells.

2. Experimental Procedure

The main focus of this research paper will be on the G field, being the closes one to the water disposal site and the field that had the biggest impact on its pressure and behaviour. The main steps for the research will be as follows:

- Conduct a thorough Overview of potentially similar studies that deals with the topic of water disposal impact in oil reservoirs

- Review basic data and understand the direct relation between the field's pressure behaviour and the injected water disposal volume[3]
- Highlight the main uncertain parameters and factors that are directly related with this type of correlation to better understand the way forward
- Determine the decline curve analysis parameters for the oil phase during the period prior Deep water disposal impact, then, compare against the decline parameters during the deep water disposal volumes, focus on stable periods only to get a good approximation[4]
- Re-examine the stable periods to acquire the decline parameters for each, utilize those for forecasting future behavior

The figure below clearly demonstrates the impact of deep water disposal rates on the performance and pressure levels of nearby fields. As the offtake increased and the disposal rates were reduced, the decline in pressure levels became more pronounced compared to the initial period.

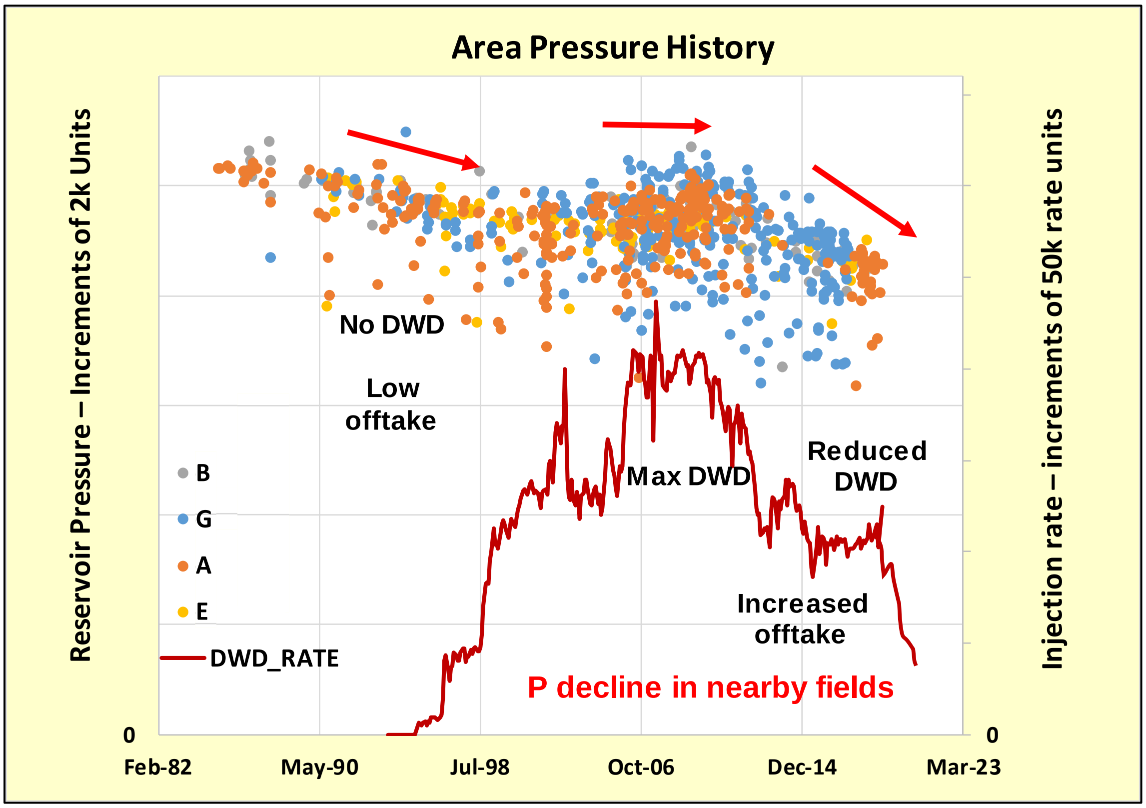

Figure 3: Nearby fields pressure response and correlation against the water disposal rates

3. Results and Discussion

Figure below highlights the main production periods identified that are linked directly with the deep water disposal injected volumes:

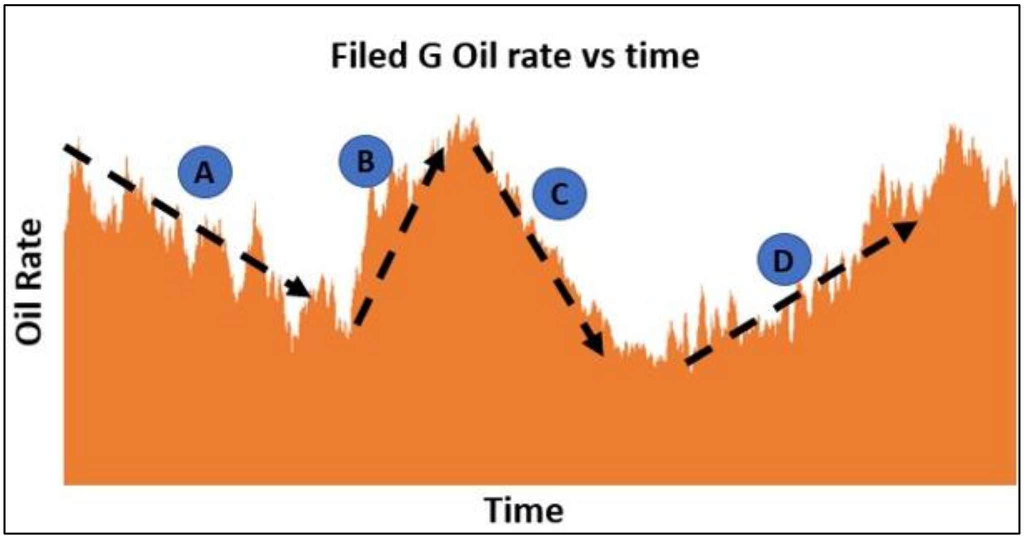

Figure 4: Field G oil rate vs time, highlighting the main periods in relation to water disposal injected volumes

By analyzing the graph above, we can identify 4 unique Oil production periods, those being:

A. The period of natural field decline, with normal offtake and the start of deep water disposal injection with lower volumes injected

B. The period where the maximum injection volumes were taking place, that saw a sharp increase in the oil rate and stabilized reservoir pressure, even with increased offtake from the reservoir

C. Sharp decline in the oil rate, with reduced water disposal volumes injected to the minimum and keeping the field offtake similar to the period before

D. Slightly increasing the water disposal volumes and reducing the reservoir offtake at a stable rate, allowing for more pressure buildup period which results in increased oil rates

Based on the above, and for our simplified forecasting assumptions, we will utilize period A decline, assuming a “max disposal” impact, and will utilize period C decline for the “minimum/No disposal” impact to forecast the behavior. The normal “current” scenario will be somewhere in between those 2 for relative comparison.[1]

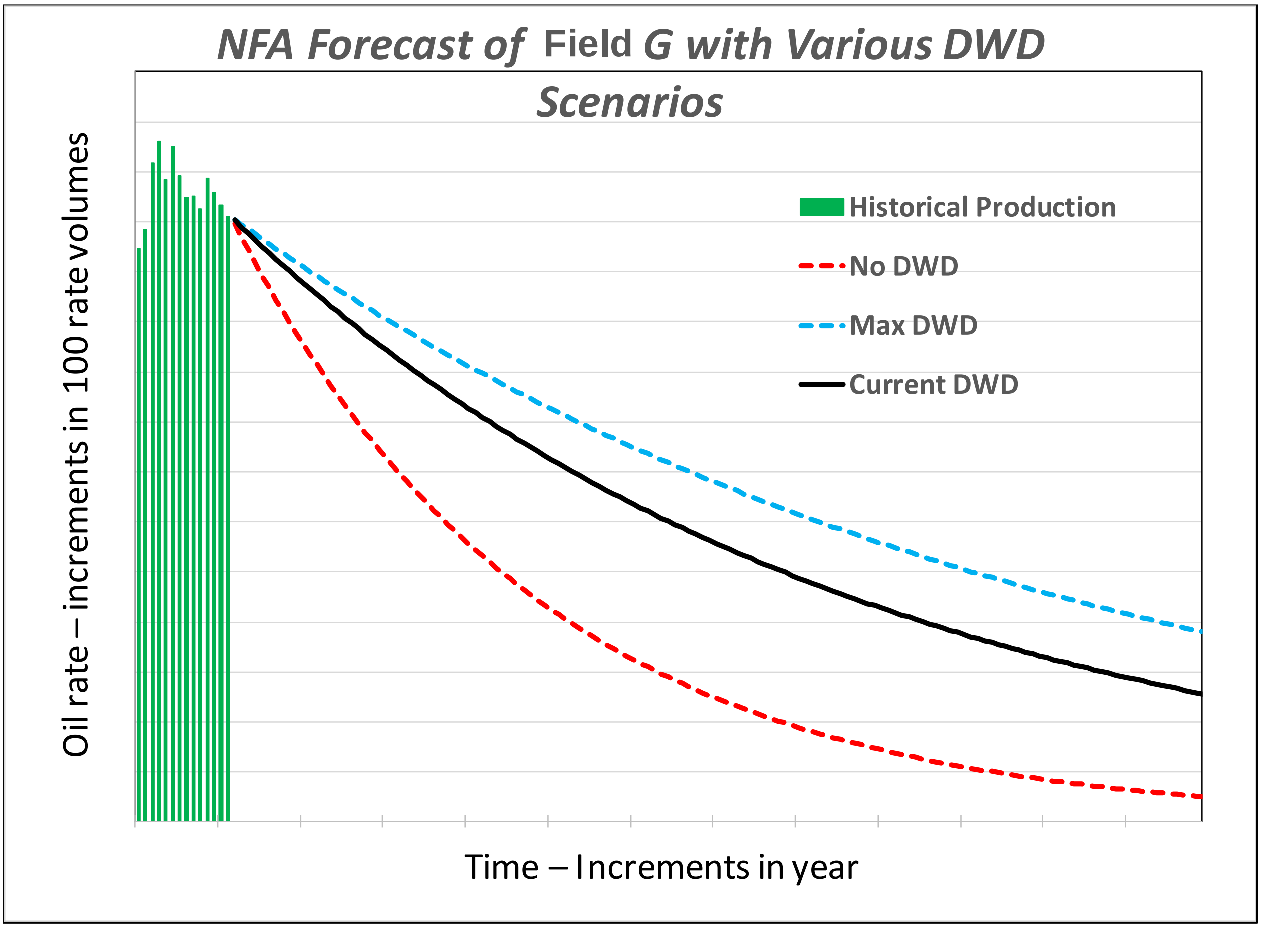

Figure 5: field forecast with Various Deep water disposal Scenarios

The perceived impact of the deep water disposal volumes is being assessed for the 3 cases below:

a. **Case 1: No Deep Water Disposal**

In this case, the G field is at a serious risk of eroding around 17% of the developed reserves due to declining pressure.

b. **Case 2: Maximum Deep water disposal volumes**

This scenario imposes extra operating costs but does deliver additional value. An estimated increase of 25% to the field's reserves can be realized from this case.it is to be noted that investments in injection and pumps equipment will be required to maintain those volumes.

c. **Case 3: Minimum water disposal volume (current)**

To maintain and support the current oil production rates this is the minimum required water disposal volumes, maintenance requires only a slight investment to keep the current surface injection facility running. This is the preferred case.

Table 1: Deep Water Disposal impact on field G reserves

Scenario	**Reserves Impact in %**

Max volume disposed	+25%
No water disposal	-17%
Minimum water disposal volume	-

4. Conclusions

- It is of absolute necessity to reclassify the deep water disposal wells into water injectors, due to the obvious relation and impact noticed from historic data, more injection equals increased pressure and vice versa.
- It is required to place an Order for certain materials that deal with surface flow measurement system since this will require a more sophisticated metering situation for proper reservoir management approach.
- Revisit assumptions and recalibrate assumption following at least 1 year of field observation and data gathering to shed brighter light on the whole situation and optimize future behavior
- Further work: Utilizing actual historical data, Build and match a zero dimension material balance model to simulate the field's behavior in relation to water disposal volumes and dynamics

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