Sudan University of Science and Technology
Collage of Petroleum Engineering
Petroleum Engineering Department

Project Submitted to College of Petroleum Engineering in Partial Fulfillment for the Degree of B.S in Petroleum Engineering

Research Titled:

Core Flooding Model For Biochemical agent (Green-zyme) to Improve Oil Recovery In Sudanese Oilfield-Case Study Hamra East

نموذج لغمر عينة اللباب باستخدام العامل البيوكيميائي (Greenzyme) لتعزيز إستخلاص النفط في الحقول السودانية ـ حقل حمرة الشرقي

Prepared By:

Abazer Awad El-tom

Mohamed Hamed Elsharif

Mohamed Ismail Adam

Osama Mohamed Bashir

Supervised by:

Engr. Husham Awadelssied Ali

October, 2017

الإستهلال

قال تعالي :

{... واتقوا الله ويعلمكم الله والله بكل شئ عليم }

صدق الله العظيم

سورة البقرة الاية (282)

Dedication

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

Our humble effort we dedicate to our sweet and loving

Fathers& Mothers,

Whose affection, love, encouragement and prays of day and night make us able to get such success and honor.

We would like to express our deepest gratitude to our supervisor **Eng. Husham Awadelssied Ali**, for his unwavering support, direction, and mentorship throughout this project.

Acknowledgement

For the ancestors who paved the path before us upon whose shoulders we stand. This is also dedicated to our families and the many friends who supported us on this journey. Thank you.

We are grateful to our project guide **Eng. Husham AwadelssedAli, Eng. Al-BadiBabiker** (GNPOC) and all the **staff of EOR lab** (ministry of petroleum).

This project would not have completed without their enormous help and worthy experience. whenever we were in need they were there behind us.

We wish to express our sincere thanks to **Dr. Tagwa Musa**, Dean of the Faculty, for the continuous encouragement**.**

Abstract

Chemical method considers as one of EOR method that is used to increase oil recovery and decreases water production through a life of reservoir, biochemical method is one of this method which depended on enzyme.

Hamra East is a Sudanese oilfield belonged to GNPOC located in Block 2B in South Kordufan with 73.3MMstb, Recovery factor of 27.3%, and high water cut.

In this project we made a simulation model for biochemical agent (greenzyme) through computer modeling group (CMG) to predict the effect of greenzyme on recovery factor, oil rate, cumulative and produce water.

From a result of a simulation model gave us we observe that greenzyme can increase oil rate, recovery factor and decrement in produce water.

التجريد

تعتبرالطرق الكيميائية واحدة من طرق الاستخلاص المعزز المستخدمة لزيادة انتاج النفط وتقليل انتاج الماء وتندرج تحتها الطرق الحيوية الكيميائية التي تعتمد علي استخدام الانزيمات .

حقل حمرة الشرقي موضوع هذا البحث يتبع لشركة النيل الكبرى يقع في ولاية جنوب كردفان مربع (2ب) يبلغ الاحتياطي 73.3 مليون برميل ومعامل الاستخلاص 27.3 % ويتصف بانتاجيته العالية من الماء .

تم اخذ التجارب المعملية التي اجريت في اللاب ثم ادخلت في برنامج CMG لعمل موديل لها للتنبؤ بتاثير هذه المادة علي معامل الاستخلاص ومعدل النفط المنتج وكذلك المياه المنتجة .

من خلال النتائج المتحصل عليها من الموديل وجد ان المادة فعالة جدا في زيادة الانتاجية للزيت وتقليل كمية المياه المنتجة .

List of Contents

Contents

Chapter Five :Conclusions and recommendations

List of Figures

List of Charts

List of Tables

Nomenclature

EOR	:	Enhanced Oil Recovery
IOR	:	Improved Oil Recovery
RDPs	:	Reservoir Development Plans
GOR	:	Gas Oil Ratio
ESP	:	Electrical Submersible Pump
ASP	:	Alkaline-Surfactant-Polymer
Co_2	:	Carbon Dioxide
N_2	:	Nitrogen
HPAM	:	Hydrolyzed Polyacrylamide
IFT	:	Interfacial Tension
HLB	:	Hydrophilic-Lipophilic Balance
CMC	:	Critical Micelle Concentration
MEOR	:	Microbial Enhanced Oil Recovery
EEOR	:	Enzyme Enhanced Oil Recovery
STOIIP	:	Stock Tank Oil Initially in Place
RF	:	Recovery Factor
EUR	:	Enhanced Ultimate Recovery
ρ_o	:	Density of Oil
ρ_w	:	Density of Water
σ_{ow}	:	Interfacial Tension between Oil and Water
USBM	:	United State Bureau of Mines
Kro	:	Relative Permeability to Oil
Krw	:	Relative Permeability to Water

μ_o	:	Oil Viscosity
μ_w	:	Water Viscosity
E_D	:	Displacement Efficiency
E_A	:	Areal Sweep Efficiency
Ev	:	Volumetric Sweep Efficiency
S_{oi}	:	initial oil saturation at start of flood
B_{oi}	:	Oil Formation Volume Factor at Start of Flood, bbl/STB
$\bar{S}_w$	:	Average Water Saturation in the Swept Area
S_{wi}	:	Initial Water Saturation at the Start of the Flood.
υ	:	Effective flow rate
θ	:	Contact Angle Measured through the fluid with highest density.
Nc	:	Capillary Number
WC	:	Water Cut
POBD	:	Barrel of Oil Per Day
API	:	American Petroleum Institute
OOIP	:	Original Oil in Place
Na2Co3	:	Sodium Carbonate
NaCl	:	Sodium Chloride
Sorw	:	Residual Oil Saturation After Water Flooding
cp	:	Centipoises
PI	:	Productivity Index
Vp	:	Pore Volume
Vb	:	Bulk Volume
K	:	Permeability
Q	:	Flow Rate
L	:	Length of Sample
D	:	Diameter of Sample
ΔP	:	Pressure Drop
DP	:	Differential Pressure
Sor	:	Residual Oil Saturation

Ko	:	Absolute Permeability to Oil
WF	:	Water Flooding
Sorw	:	Residual Oil Saturation after Water Flooding
KPI	:	Key Performance Indicator
GZ	:	Greenzyme
H.E	:	Hamra East
GNPOC	:	Greater Nile Petroleum Operating Company

Chapter One: Introduction

1.1 General Introduction:

In the last few years, Enhanced Oil Recovery (EOR) processes have re-gained interest from the research and development phases to the oilfield EOR implementation. This renewed interest has been furthered by the current high oil price environment, the increasing worldwide oil demand, the maturation of oilfields worldwide, and few new-well discoveries (Aladasani , 2010).

Enhanced oil recovery is generally considered as the third, or last, phase of useful oil production, sometimes called tertiary production. The first, or primary, phase of oil production begins with the discovery of an oilfield using the natural stored energy to move the oil to the wells by expansion of volatile components and/or pumping of individual wells to assist the natural drive. When this energy is depleted, production declines and a secondary phase of oil production begins when supplemental energy is added to the reservoir by injection of water. As the water to oil production ratio of the field approaches an economic limit of operation, when the net profit diminishes because the difference between the value of the produced oil and the cost of water treatment and injection becomes too narrow, the tertiary period of production begins. Actually, EOR may be initiated at any time during the history of an oil reservoir to stimulate production. The combined total oil production by primary and secondary methods is generally less than 40% of the original oil in place. Thus the potential target for EOR is greater than the reserves that can be produced by conventional methods. (Aladasani , 2010).

1.1.1 EOR Definitions:

EOR Refers to any method used to recover more oil from a reservoir than would not be obtained by primary recovery ".(Teknica,2001)

The injected fluids must accomplish several objectives as follows :

I. Boost the natural energy in the reservoir.
II. Interact with the reservoir rock/oil system to create conditions favorable for residual oil recovery that include among others:
    1. Reduction of the interfacial tension between the displacing fluid and oil.
    2. Increase the capillary number.

3. Reduce capillary forces.
4. Increase the drive water viscosity.
5. Provide mobility-control.
6. Oil swelling.
7. Oil viscosity reduction.
8. Alteration of the reservoir rock wettability.

The ultimate goal of EOR processes is to increase the overall oil displacement efficiency, which is a function of microscopic and macroscopic displacement efficiency.

Microscopic efficiency refers to the displacement or mobilization of oil at the pore scale and measures the effectiveness of the displacing fluid in moving the oil at those places in the rock where the displacing fluid contacts the oil (Green, 1998).

For instance, microscopic efficiency can be increased by reducing capillary forces or interfacial tension between the displacing fluid and oil or by decreasing the oil viscosity (Satter et al., 2008)

1.1.2 IOR and EOR definition:

Improved oil recover "IOR" is any of the various methods, chiefly reservoir derives mechanisms and enhanced recovery techniques, designed to improve the flow of hydrocarbons from reservoir to wellbore or recover more oil after the primary or secondary methods (water and gas floods) are uneconomic.

- Enhanced oil recovery or EOR is "one or more of a variety of processes that seek to improve the recovery of hydrocarbon from a reservoir after the primary production phase .**(**Vladimir**,** 2010)

1.1.3 Development Sequence:

Reservoir Development Planning refers to strategies that begin with the exploration and appraisal well phase and end with the abandonment phase of aparticularfield to establish the course of action during the productive life of the asset. The main objective of the complete cycle of a development plan is to maximize the asset value. (Vladimir, 2010)

Development Strategies for new fields are based on data obtained from seismic surveys, exploratory wells, and other limited information sources such as fluid properties and reservoir analogues. Based on the information at hand, initial development plans are defined through simulation studies considering either a probabilistic or astochastic approach to rank options using economic indicators, availability of injection fluids (i.e., water and/or gas), and oil recovery and risk, among other considerations.

Therefore, integrating the information from simulation studies helps to address the multiple and complex factors that influence oil recovery, as well as reservoir development decisions. as new information about the reservoir, its geology, and its degree of heterogeneity becomes available through drilling of new wells and production–injection history, the field can be developed in an optimal way.

In the case of mature fields with a steady decline in oil production, new development plans must be revaluated or implemented. However, if the decision to implement a new development plan in mature fields is made too late, the number of economically viable options becomes limited. For a variety of reasons, most, if not all, reservoir development plans (RDPs) change or must be adjusted or modified during the productive life of the field. (Vladimir, 2010)

1.2 Oil Recovery Mechanisms:

1.2.1 Primary Recovery:

Primary oil production (primary oil recovery) is the first method of producing oil from a well and depends upon natural reservoir energy to drive the oil through the complex pore network to producing wells. If the pressure of the fluid in the reservoir (reservoir energy) is great enough, the oil flows into the well and up to the surface. Such driving energy may be derived from liquid expansion and evolution of dissolved gases from the oil as reservoir pressure is lowered during production, expansion of free gas, or a gas Cap, influx of natural water, gravity, or combination-ns of these effects.

In fact, crude oil moves to the well by one or more of primary production three processes. They are: dissolved gas drive, gas cap drive, and water drive. (James G,2014)

Dissolved Gas Drive

The propulsive force is the gas in solution in the Oil, which tends to come out of solution because of the pressure release at the point of penetration of a well. It's the least efficient type drive it is to control the GOR, the bottom-hole pressure drops rapidly and the total the total eventual recovery may be less than 20%.(James G,2014)

Gas Cap Drive

The propulsive force is the a gas cap and contains methane and other hydrocarbons that may be separated out by compressing the well, the retrograde condensate pools because decrease (instead of an increase) in pressure brings about condensation of the liquid hydrocarbons. When this reservoir fluid is brought to the surface and the condensate is removed, a large volume of residual gas remains, The modern practice is to cycle this gas by compressing it and inject it back into the reservoir, thus maintaining adequate pressure within the gas cap, and condensation in the reservoir is prevented, The recovery about 40% -50%.(James G, 2014).

Water Drive

The propulsive force is the water drive which is considered most efficient propulsive force, it is essential that the removal rate be adjusted so that the water moves up evenly as space is made available for it by the removal of the hydrocarbons. An appreciable decline in bottom-hole pressure is necessary to provide the pressure gradient required to cause water influx. The recovery is as high as 80%. (James G,2014)

Gravity drainage drive

The mechanism of gravity drainage occurs in petroleum reservoirs as a result of differences in densities of the reservoir fluids. The effects of gravitational forces can be simply illustrated by placing a quantity of crude oil and a quantity of water in a jar and agitating the contents. After agitation, the jar is placed at rest, and the more dense fluid (normally water) will settle to the bottom of the jar, while the less dense fluid (normally oil) will rest on top of the denser fluid. The fluids have separated as a result of the gravitational forces acting on them. (TarekAhmed, 2010)

Combination drive

The driving mechanism most commonly encountered is one in which both water and free gas are available in some degree to displace the oil toward the producing wells. (Tarek Ahmed, 2010)

1.2.2 Secondary Recovery:

This method is used when the pressure be insufficient underground pressure to force the crude oil to the surface. It's aid in recovering oil from depleted reservoirs. By using some techniques increase the reservoir pressure by water injection, natural gas reinjection and gas lift, air, carbon dioxide , nonreactive gas, pumps on the surface (balanced-beam submerged pumps ,horse head pump, sucker rod pump),submerged pumps (ESPs) are also used to provide mechanical lift to the fluids in the reservoir. The success of secondary recovery processes depends on the mechanism by which the injected fluid displaces the oil (displacement efficiency) and on the volume of the reservoir that the injected fluid enters (conformance or sweep efficiency). Water injection is still predominantly and secondary recovery process but if some channels in the reservoir are larger than others and the water tends to flow freely through these, bypassing smaller passages where the oil remains, a partial solution to this problem is possible by miscible fluid flooding, butane and propane are pumped into the ground under considerable pressure, dissolving the oil and carrying it out of the smaller passages; additional pressure is obtained by using natural gas. (James G, 2014)

The purposes of a secondary recovery technique are:

- Pressure restoration
- Pressure maintenance

The mechanism of secondary oil recovery is similar to that of primary oil recovery except that more than one well bore is involved**.**

Water injection

In water injection operation, the injected water is discharged in the aquifer through several injection wells surrounding the production well. The injected water creates a bottom water drive on the oil zone pushing the oil upwards. The water injection is generally carried out when solution gas drive is present or water drive is weak. Therefore for better economy the water injection is carried out when the reservoir pressure is higher than the saturation pressure.

Water is injected for two reasons:

1. For pressure support of the reservoir (also known as voidage replacement).

2. To sweep or displace the oil from the reservoir, and push it towards an oil production well.

The selection of injection water method depends upon the mobility rate between the displacing fluid (water) and the displaced fluid (oil).

The water injection however, has some disadvantages, some of these disadvantages are:

• Reaction of injected water with the formation water can cause formation damage.

• Corrosion of surface and sub-surface equipment.

As part of water injection it is also common to find the water flooding technique. Water flooding consists of water is injected into the reservoir through injection wells. The water drives oil through the reservoir rocks towards the producing wells. (James G,2014)

Gas injection

It is the oldest of the fluid injection processes. This idea of using a gas for the purpose of maintaining reservoir pressure and restoring oil well productivity was suggested as early as 1864 just a few years after the Drake well was drilled. The first gas injection projects were designed to increase the immediate productivity and were more related to pressure maintenance rather to enhanced recovery. Recent gas injection applicat-ions, however, have been intended to increase the ultimate recovery and can be considered as enhanced recovery projects. In addition, gas because of its adverse viscosity ratio (higher mobility ratio) is inferior to water in recovering oil. Gas may offer economical advantages. Gas injection may be either a miscible or an immiscible displacement process. The characteristics of the oil and gas plus the temperature and pressure conditions of the injection will determine the type of process involved. The primary problems with gas injection in carbonate reservoirs are the high mobility of the displacing fluid and the wide variations of permeability. It is required a much greater control over the injection process than the one necessary with water-flooding. In order to evaluate the weep efficiency of the planned gas injection, a short-term pilot gas injection test should be driven. At the same time, this test would provide the necessary data to calculate the required volumes of gas; this in turn, will aid in the design of compressor equipment and estimating the number of injection well which will be required. The benefits obtained by the gas injection are dependent upon horizontal and vertical sweep efficiency of the injected gas. The sweep efficiency depends on the type of porosity system present.(James G,2015)

1.2.3 Tertiary recovery:

Is that additional recovery over and above what could be recovered by primary and secondary recovery methods. Various methods of enhanced oil recovery (EOR) are essentially designed to recover oil, commonly described as residual oil, left in the reservoir after both primary and secondary recovery methods have been exploited to their respective economic limits.

During tertiary oil recovery, fluids different than just conventional water and immiscible gas are injected into the formation to effectively boost oil production. Thus EOR can be implemented as a tertiary process if it follows a water flooding or an immiscible gas injection, or it may be a secondary process if it follows primary recovery directly. Nevertheless, many EOR recovery applications are implemented after water flooding (Lake, 1989; Lyons &Plisga, 2005; Satter et al., 2008; Sydansk& Romero-Zerón, 2011). At this point is important to establish the difference between EOR and Improved Oil Recovery (IOR) to avoid misunderstandings. The term Improved Oil Recovery (IOR) techniques refers to the application of any EOR operation or any other advanced oil-recovery technique that is implemented during any type of ongoing oil recovery process. Examples of IOR applications are any conformance improvement technique that is applied during primary, secondary, or tertiary oil recovery operations. Other examples of IOR applications are: hydraulic fracturing, scale-inhibition treatments, acid-stimulation procedures, infill drilling, and the use of horizontal wells.(Lake, 1989)

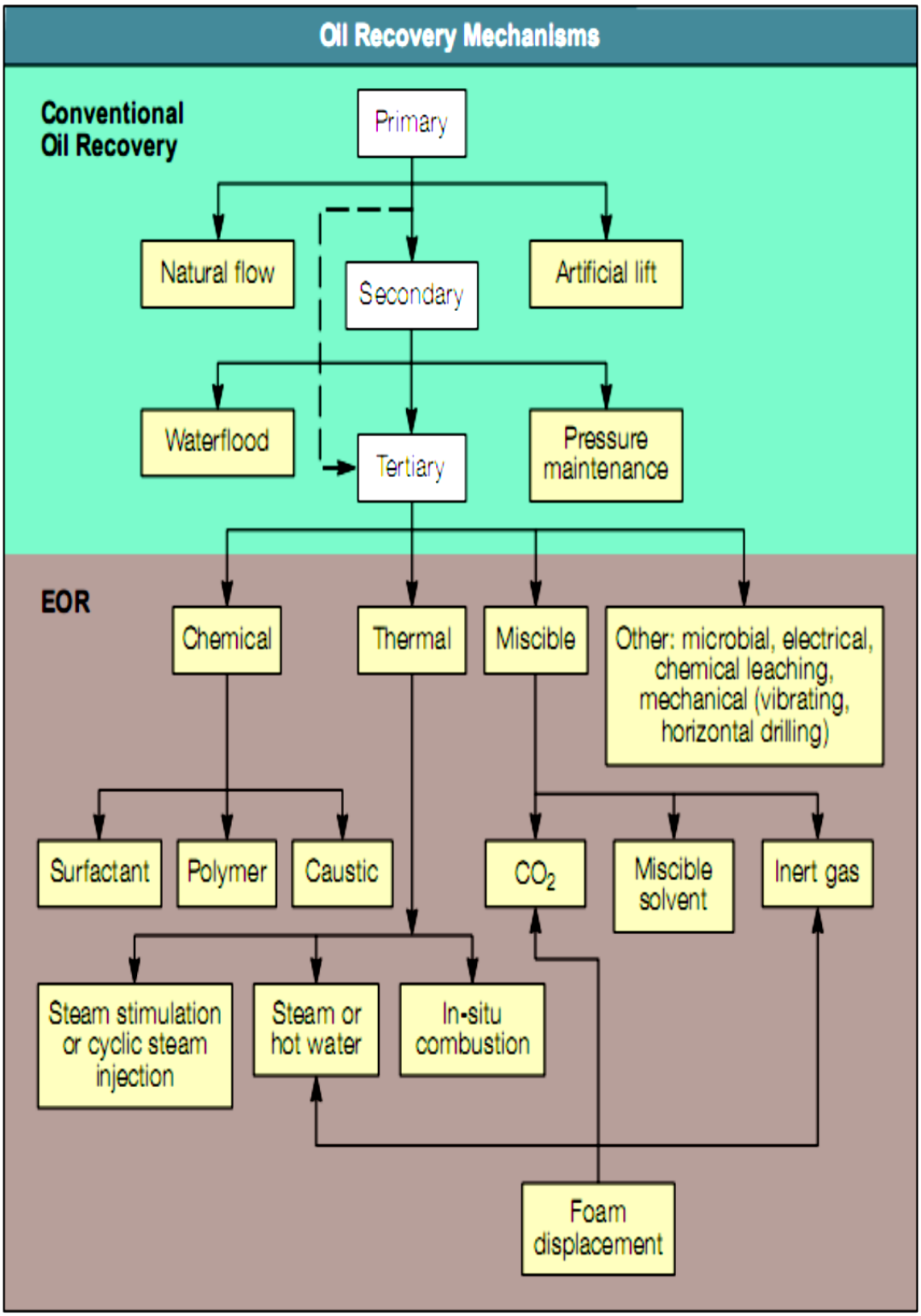


Figure (1. 1) Oil Recovery Mechanism (Schmidt,1990).

1.3 Classification of EOR Processes:

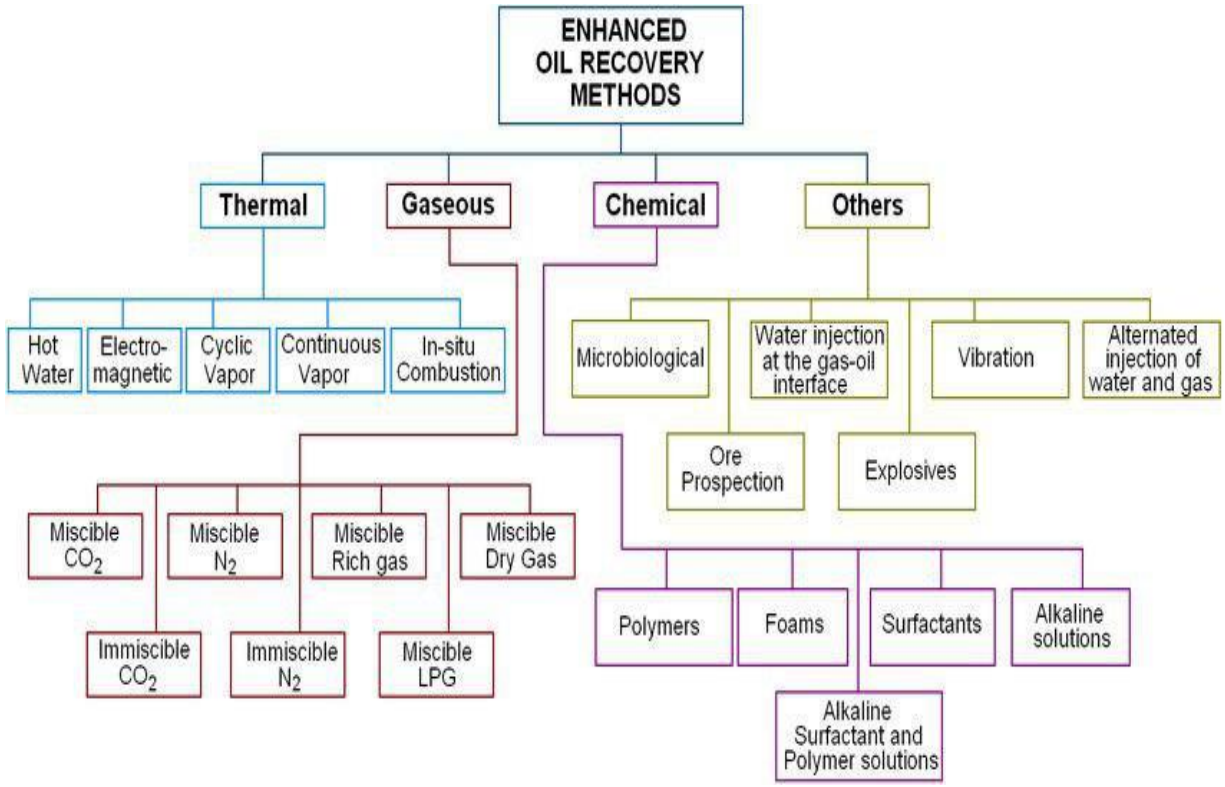


Figure (1. 2) Some Enhanced Oil Recovery Methods(A. Gurgel,2008)

The main objective of all methods of EOR is to increase the volumetric (macroscopic) sweep efficiency and to enhance the displacement (microscopic) efficiency, as compared to ordinary water flooding. One mechanism is aimed towards the increase in volumetric sweep by reducing the mobility ratio between the displacing and displaced fluids. Since the mobility of the injected fluid is reduced, the tendency to the fingering effect is much lowered.

The other mechanism is targeted to the reduction of the amount of oil trapped due to the capillary forces (microscopic entrapment). By reducing interfacial tension between the displacing and displaced fluids the effect of microscopic trapping is lowered, yielding a lower residual oil saturation and hence higher ultimate recovery. So, the final recovery factor depends upon the microscopic displacement efficiency and on volumetric efficiency of the displacement front (GL Chierici, 1995).

There are four major categories of enhanced oil recovery:

1. Chemical Process

2. Thermal Recovery

3. Miscible Injection

4. Other (Microbial, electrical)

1.4 Chemical EOR:

Chemical Injection: This EOR technique is used to free the hydrocarbons from the pores by injecting long chained molecules, “polymers” into the reservoir. This injection of polymers increases the effectiveness of the water floods. A detergent in the form of a, “Surfactant” can also be used; which act as cleansers and lowers the surface tension which then prevents the oil droplets from moving through the oil reservoir. The principle chemical EOR techniques consist of injecting, “Polymer surfactants, polymer flooding and alkaline flooding."(Mr.Saahil 2015)

There are four common types of chemical EOR methods namely:

1- Polymer flooding

2- Surfactant flooding

3- Alkaline flooding

4- Alkaline –surfactant-polymer (ASP) flooding

1.4.1 Polymer flooding

Two types of polymer are used in enhance oil recovery: synthetic polymers like partial hydrolyzed polyacrylamide (HPAM) and bio-polymer like xanthan.HPAM type of polymers are much more widely used than biopolymer (xanthenes type), because HPAM has advantage in price and large-scale production. (James J, 2013)

Mechanism

The main mechanism of polymer flooding is the increased viscosity of polymer solution so that the mobility ratio of the displacing polymer solution to the displaced fluids ahead is reduced and the viscous fingering is reduced. When the viscous fingering is reduced, the sweep efficiency is improved. (James J, 2013)

Mobility control

Generally, for a water drive with in a homogenous reservoir, an unfavorable mobility ratio often exists because the injected water viscosity is lower than the oil viscosity. This result will induce the fraction of water phase (water cut) during liquid production to rise rapidly. As a consequence, the sweep efficiency will be very low, due viscous fingering. However by increasing the polymersolution, the mobility ratio canbeimproved, (JamesJ, 2013)

1.4.2 Surfactant Flooding :

Surfactant

This term is a blend of surface-acting agents that adsorb on or concentrate at a surface or fluid/fluid interface to alter the surface properties significantly; in particular, they decreases surface tension or interfacial tension (IFT). Surfactants are usually organic compounds that are amphiphilic, meaning they are made up of two functional groups; hydrophobic (water-hating, the "tail") and polar hydrophilic (water-loving, the "head").(James J, 2013)

Surfactant may be classified according to the ionic nature of the head group as aninic, cationic, nonionic, andzwitterionic the main advantage tension or interfacial tension (IFT). (Johannes, 2012)

Parameter to characterize surfactant

The parameter to characterize surfactant hydrophilic-lipophilic balance (HLB), critical micelle concentration (CMC), Kraftpoint, solubilization ratio, R-ratio, and packing number.

Mechanisms of surfactant flooding

The key mechanism for surfactant flooding is lowering interfacial tension (IFT)effect to discuss the mechanism , the concept of capillary number vs residual oil saturation discussed first .

1.4.3Alkaline Flooding :

Also called a caustic flooding. Alkalis used in alkaline related EOR include sodium hydroxide, sodium carbonate, sodiumorhtosilicate, sodium tripolyphosphate, sodium metaborate, ammonium hydroxide and ammonium carbonate .(James J, 2013)

Alkaline reaction with crude oil:

In alkaline flooding, the injected alkali reacts with the soaponifiable components in the reservoir crude oil. These saponifiable components are describe as a petroleum acid. (James J, 2013)

Mechanisms

One mechanism of alkaline flooding is that a surfactant (called soap to differentiate it from an injected synthetic surfactant) is generated in situ when an alkaline solution reacts with the acid component in a crude oil.

1.4.4 Alkaline Surfactant Polymer Flooding:

Polymers can be used for mobility control. The interaction between polymers and surfactants is shown to be affected by pH, ionic strength, crude oil type, and the properties of the polymers and surfactants. (French, 1993)Surfactants, whose major components are natural mixed carboxylates from the heels of vegetable oil and fats such as soybean oil, vegetable oil, animal oil, and tea oil, etc., have been developed. Optimal formulations were obtained using an orthogonal-test-design method to screen the alkaline surfactant polymer flooding system. The oil recovery can be increased by 26.8% of the original oil in place in a core flood experiment. The waste water resulting from the production of the natural mixed carboxylates also exhibit a high surface activity. (Johannes,2012

Advantages:

1-Alkaline injection reduces the adsorption of surfactant and polymer

2-Alkali reacts with crude oil to generate soap. Soap has low optimum salinity, whereas a synthetic surfactant has relatively high optimum salinity. The mixture of soap and the synthetic surfactant has a wider range of salinity in which the IFT is low.

3- Emulsions improve the sweep efficiency. Soap and surfactant make emulsions stable owing to the reduced IFT. Polymer may help to stabilize emulsions owing to its high viscosity to retard coalescence.

4-There is a competition of adsorption sites between polymer and surfactant. Therefore, adding polymer reduces surfactant adsorption, or vice versa.

5-Adding polymer improves the sweep efficiency. (James J, 2013)

1.5Greenzyme:

1.5.1 Background of EEOR:

Enzyme Enhanced oil recovery is a process which is aimed at mimicking the effect of MEOR or Microbial Enhanced Oil Recovery. A sub-category of MEOR involves the microbial product being Bio surfactants which serve the following purposes:

- Reduce Interfacial tension between oil and rock/water surface
- Leading to emulsification
- Improving pore scale

EEOR also serves the following needs as have been discussed in the previous section. Microbial enhanced oil recovery refers to the use of microorganisms to retrieve additional oil from existing wells, thereby enhancing the petroleum production of an oil reservoir. In this technique, microorganisms are introduced into oil wells to produce harmless by-products, such as slippery natural substances or gases all of which help propel oil out of the well. Because these processes help to mobilize the oil and facilitate oil flow, they allow a greater amount to be recovered from the well.

1.5.2 What Are Enzymes:

Enzymes are biological catalysts made of proteins that catalyze (i.e. significantly accelerate) specifically desired biological chemical reactions between a substrate (oil), the water medium and formation. The enzymes lower the activation energy needed for the reaction without being consumed. Enzymes can catalyze up to several million reactions per second. Our enzymes are engineered with an active site having a strong affinity for the oil. (Tarang Jain, 2012)

1.5.3Working mechanism:

Similar to the oil wet system. a water wet system is characterized by the major part of the rock surface to be wetted by the water phase. In such an arrangement the water exists more or less as a continuous film through pores and open channels and the oil is resting on a film of water. Such a system is also typical for a result of a process referred to as snap-off of oil. This is a system where water is pushing oil through pore

throats and droplets of oil are released from the main oil globule by a snap-off. This process leaves trapped oil drops in pores.

‘When the enzyme — water solution floods and replaces the water or brine phase in such a system, the solid surfaces also become wetted by an enzyme — water phase. In addition the enzyme recognizes — attaches to and releases hydrocarbons from the oil globule. This in turn drastically reduces the surface tension between the oil globule and aqueous phase. The reduction in interfacial Tension (IFT) between the oil and hydrocarbon is documented by separate lab measurements. These effects in turn cause release of oil droplets from the parent oil globule and the now formable shape of the parent oil globule makes it subject to be pushed out of the pore in the direction of flow for the displacing fluid. This situation is schematically shown in Figure below. Model sketch of oil releasing mechanism of enzymes in a typical water wet system. Red spots indicate a few enzyme molecules attached to oil globule surface. The enzyme wetted surfaces of the solids are not marked.

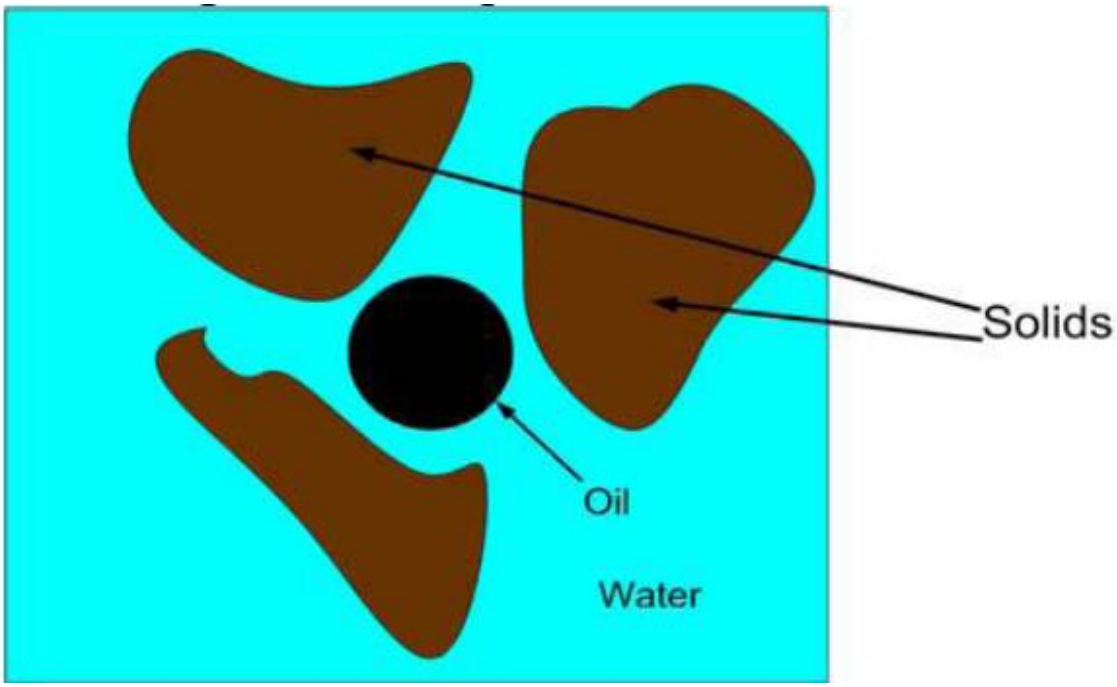


Figure (1. 3) EEOR In Water Wet System (Tarang Jain,2012)

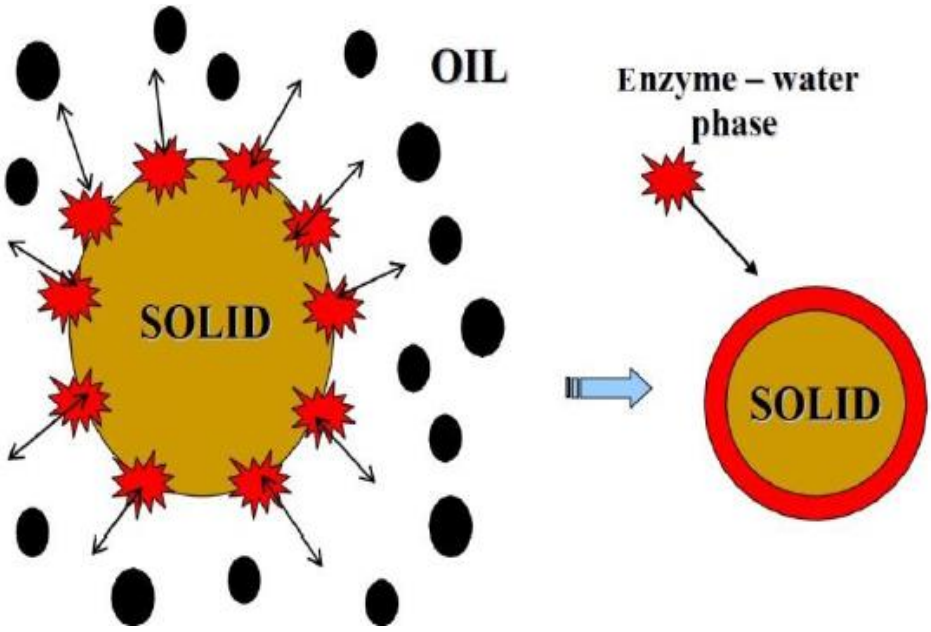


Figure (1. 4) Greenzyme Mechanism With Sand (Tarang Jain,2012)

The environment-friendly enzyme agent is a water soluble product which can strongly release oil from reservoir grain surface, it can alter pay rock from oil-wet to water-wet, and reducing interfacial tension of grains and oil flow resistance through pores (Qing-xian Feng,2007)

1.5.4 Advantage Of EEOR :

1. Reduce interfacial tension between oil and rock / water surface
2. Improving pore scale
3. The well stimulation process with the enzyme technology is very simple
4. Economically
5. The effect of enzyme could last for years (Tarang Jain,2012)

1.6 Problem statement:

In Hamra oil field, the production rates started to decline in high rates after water flooding because of high part of the remaining oil (residual oil saturation) is still trapped in the porous media due to capillary force and high water cut production, experimental study of improve oil recovery factory by using oil biochemical agent (Greenzyme) which can lower the interfacial tension and hence decrease the capillary force.

1.7 Objectives of the study:

The main objectives of this research are:

1-To simulate the implementation of using Grenzyme through CMG software in hamra-east oil field

3- show the effect of greenzyme on oil rate , cumulative and recovery factor.

4- Compare between laboratory experiments tests and Greenzyme properties in hamra-east-8 well and worldwide fields.

1.8 Introduction to the case study:

Hamra Cluster 2B is located in Block 2B South Kordufan it was put to productionin January 2012 , and it consist of three structures i.e. Hamra Central ,Hamra East and Hamra South East. With the following tables show the general information of these three structures :

Table (1. 1) General properties of Hamra Cluster 2B structures

Reservoir	STOIIP	RF	EUR	Production		Reserves (2P)		Potential
	2P	(%)	@Dec-2031	2017.1-4	Cum	DEV	UNDEV	Recovery
Hamra Central	24.09	5.7	1.38	0.04	1.09	0.29	0	0
Hamra East	73.34	27.3	20.01	0.44	13.02	5.14	1.85	0
Hamra Southeast	4.98	50.6	2.52	0.09	1.23	1.29	0	0
Total (MMB)	**102.41**	**23.3**	**23.90**	**0.57**	**15.34**	**6.71**	**1.85**	**0**

Table (1. 2) Numbers Of Wells In The Three Structures

Structures	Total Wells	Wells Status			Completion Types		
		Active Producers	Active Injectors	Idle Wells	Vertical Wells	Deviated Wells	Horizontal Wells
Hamra E	26	23	0	3	25	1	/
Hamra SE	2	2	/	/	2	/	/
Hamra C	5	4	/	1	5	/	/
Total	33	29	0	4	32	1	0

The field production in April2017 was around 21985 BOPD with oil rate 4972 and water cut 77% , the cumulative oil was MMSTB(14.98 of OOIP)

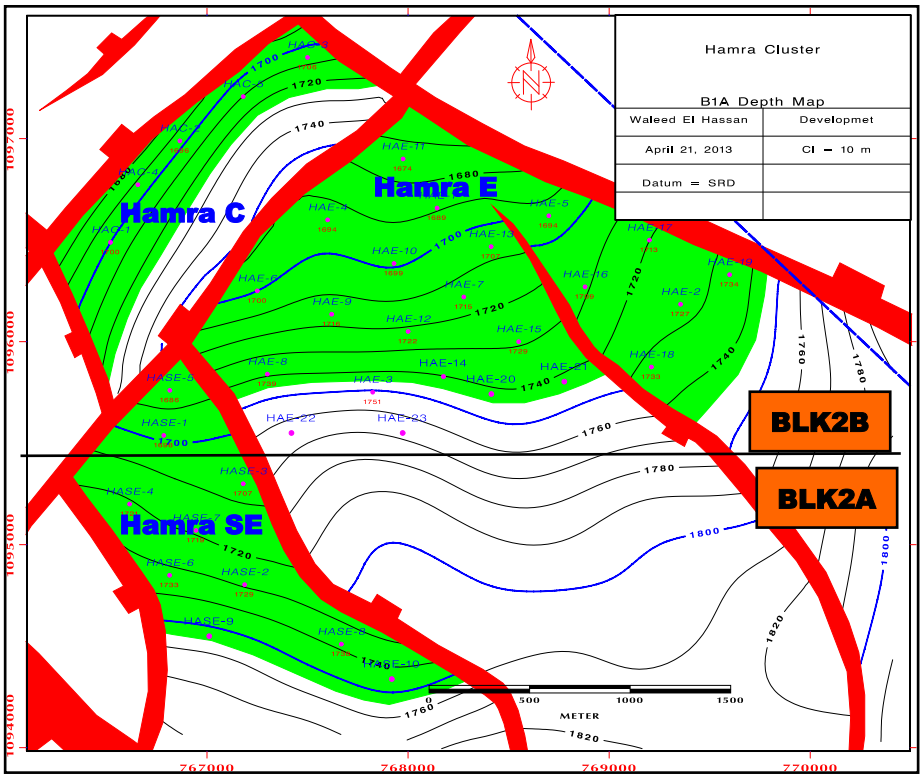


Figure (1. 5) Hamra Oilfield Location Map

1.9 Thesis out lines:

Chapter one in thesis is including a general introduction of EOR method and biochemical agent (Greenzyme), chapter two contain the literature reviews and theoretical background of the study, while chapter three is talking about the laboratory experiment methodology and steps. Chapter 4 is summarizing the result discussion of the work in form of table and charts chapter 5 is conclusion and recommendation.

Chapter Two

Theoretical Background and Literature Reviews

2.1 Theoretical Background

2.1.1 Introduction

Oil production in many fields has reached the mark of residual oil saturation. This in turn has forced the oil industry to recover oil from more complicated areas, where the oil is less accessible, by means of advanced recovery techniques. The reserves and production ratios in sandstone fields have around 20 years of production time left. The proven and probable reserves in carbonate fields have around 80 years of production time left (montaron, 2008).

With global energy demand and consumption forecast to grow rapidly during the next 20 years, a more realistic solution to meet this need lies in sustaining production from existing fields by means of EOR (James, 2010).

After primary and secondary methods, two-thirds of the original oil in place (OOIP) in a reservoir is not produced and still pending for recovery by efficient enhanced oil recovery(EOR) methods. EOR methods can be categorized into three main processes such as Thermal oil recovery, miscible flooding, and chemical flooding (taber et al. 1979).

2.1.2 When to start EOR

A common procedure for determining the optimum time to start EOR process after water flooding depends on:

i. Anticipated oil recovery.

ii. Fluid production rates.

iii. Monetary investment.

iv. Costs of water treatment and pumping equipment.

v. Costs of maintenance and operation of the water installation facilities.

vi. Costs of drilling new injection wells or converting existing production wells into

injectors.(Tarek Ahmed, 2001)

2.1.3 Basic concepts:

Interfacial tension :

The surface tension is defined as the force exerted on the boundary layer between liquid phase and a vapor phase per unit length. This force is caused by differences between the molecular forces in the vapor phase and those in the liquid phase, and also by the imbalance of these forces at the interface. The surface can be measured in the laboratory and is unusually expressed in dynes per centimeter (Tarek Ahmed, 2010).

$$\sigma_{ow} = \frac{r\ h\ g\ (\rho_w - \rho_o)}{2a2\cos\theta}$$

Where:

r = pore radius, cm

h = height, cm

ρo= density of oil, gm/cm.

ρw= density of water, gm/cm.

σow= interfacial tension between the oil and the water, dynes/cm.

***Wettability*:**

Wettability is the preference of one fluid to spread on or adhere to a solid surface in the presence of other immiscible fluids (Craig, 1971).

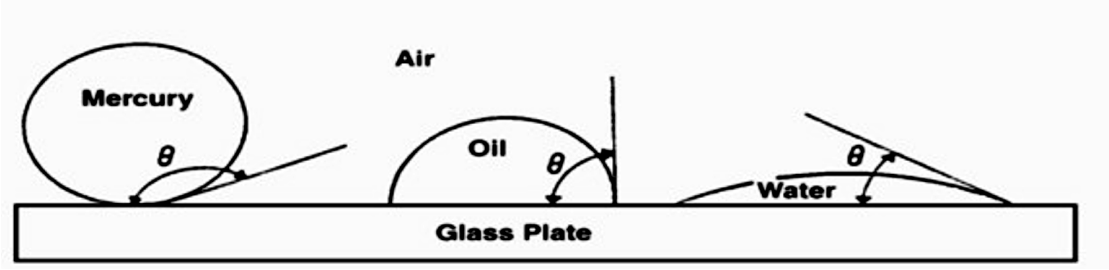


Figure (2. 1) Illustration of Wettability(Craig, 1971)

Wettability depends on the mineral ingredients of the rock, the composition of the oil and water, the initial water saturation, and the temperature. The wettability of reservoir rocks to the fluids is important in that the distribution of the fluids in the porous media is a function of wettability. Because of the attractive forces, the wetting phase tends to occupy the smaller pores of the rock and the non-wetting phase occupies the more open channels (Tarek Ahmed, 2010).

Wettability can be quantified by measuring the contact angle of oil and water on silica or calcite surface or by measuring the characteristics of core plugs with either an Amott imbibitions test or a USBM test.

Mobility ratio:

Tarek Ahmed (2000) states that The mobility is defined as the ratio of the permeability to the viscosity and the Mobility ratio (M) is defined as the mobility of displacing phase to mobility of displaced phase, and can be given by:

$$M = \frac{\lambda \text{ displacing}}{\lambda \text{ displaced}}$$

$$M = \frac{\frac{Krw}{Kro} * \mu o}{\mu w}$$

Where :

Kro, Krw= relative permeability to oil and water, respectively.

μo ,μw= viscosity of oil and water, respectively.

If a mobility ratio greater than unity, it is called an unfavorable ratio because the invading fluid will tend to bypass the displaced fluid. It is called favorable if less than

unity and called unit mobility ratio when equal to unity.

Recovery factor:

The overall recovery factor (efficiency) RF of any secondary or tertiary oil recovery method is the product of a combination of three individual efficiency factors as given by the following generalized expression:

$RF = E_D E_A E_V$

Where:

RF = overall recovery factor

ED = displacement efficiency

EA = areal sweep efficiency

EV = vertical sweep efficiency

Capillary Number:

Capillary Number is defined as the ratio of the viscous forces and local capillary forces. This can be calculated from the formula in equation below (Moore and Slobod 1955):

$$Nc = \frac{u\mu w}{\sigma \cos\phi}$$

Where:

u= Effective flow rate

μ = Viscosity of displacing fluid

σ = Interfacial Tension

O = Contact angle measured through the fluid with highest density.

An increase in capillary number implies a decrease in residual oil saturation and thus an increase in oil recovered.

2.2 Literature Reviews:

2.2.1 Case Study Worldwide:

In February 2015 Mr.Saahil Vaswani1, Mr.Mohd Ismail Iqbal2, Dr.Puspha-Sharma ,studied the chemical injection EOR method, "Alkaline/ Surfactant/ Polymer on depleted reservoirs , after ASP was applied the result shows that oil production rate from the field at the start of process was about 60m3/d. after initiation of ASP, the oil production rate reaches the peak level of about 180m3/d. chemical movement has

been fast resulting in drop in water cut. Initial water cut at the start was over 80% and gradually dropped to about 75%.

In 2002 Li JiaHuaconducted analysis of single well stimulation done for Shengli oilfield china using Greenzyme,lun 2-25 well have been selected , result show that daily fluid production increase from 6 t/d to 13.6 t/d , viscosity drops from 19.2 Mpa.s to 16-9 Mpa.s, the water content was kept below 60% level and the geological formation near bottom hole and vicinity areas show significant improvement in fluid flow mobility.

In 2007 John L Gray conducted analysis of EEOR using Greenzyme for prue Ranch (Anacacho) oil field – Texas after the field production started declining , the treatment included acidizing the well before injecting the Greenzyme, the results showed a clear and sustained increase in production after treatment with Greenzyme . Peak average monthly production of 8.81 BOPD which was double of average production of 4.34 POBD , the results also showed that the enzyme fluid can be effective for higher API gravity oil (ie. 34 API gravity)

In 2009 Hamidreza Nasiri conducted a laboratory experiment study on use of enzymes to improve water flood Performance ,the aim of the study is to determine the effect of Greenzyme on wettability by flooding the cores with different types of enzymes and measuring the Contact Angle , Interfacial Tension and crude oil Viscosity the results shows : contact angle measurement indicate more water – wet behavior using enzyme especially (Greenzyme) , IFT between oil and brine solution containing Greenzyme has lower value , the oil recovery increased from 3.5% to 11% OOIP and for cores in this study less change in wettability than expected was observed.

In 2011William K. Ott studied the successes of EEOR for Mann Field-Myanmar, the treatment was applied in two wells (well 101 , well 395) by injecting ofa concentrated, water-soluble enzyme preparation made from DNA-modified proteins released from selected microbes in oil zones of the first well and then recycled and applied in a second well and the results were improvement in oil production in the two wells and indicated that modified enzyme solution can effectively be recycled into other wells to enhance production , diverting Modified enzyme treatments into more intervals should improve treatments results and tests indicate it is more effective in high water cut well.

In 2011 Liu He studied the Biology enzyme EOR for low permeability reservoirs, laboratory experiment was conducted by applying 4 types of biology enzymes solution with different concentration ranging from 0.4% to 5% to conduct depressurization on 6 artificial cores and 3 natural cores the results showed that the biology enzyme may cause depressurization stimulation effect in low permeability reservoirs and that the biology enzyme plays a part in releasing rock piratical surface hydrocarbon

In 2007 Chuck Devier conducted a Greenzyme core flood laboratory experiment, two core samples were selected for the core flood test under overburden conditions , the lab results showed decrease in IFT and SOR and increment in oil production.

In 2000, Petroleos de venezuela, S.A. (PDVSA),conducted Greenzyme EOR treatment for reason of decline in production level, Well TJ1319 was chosen to receive multiple treatments of Greenzyme, to test whether the recovery factor would increase after each treatment, the results show that Initial fluid production increased with produced water being extracted first, followed by oil production. Treatments effectively removed wellbore blockage for improved relative permeability. Increased recovery was maintained as long as seven months in one case, before starting to decline. Greenzyme was found to be effective in any type of oil environment (heavy, medium, light). Average production increase of 335% and 440,703barrels of additional oil.

In 2008,Y. Wang, studied a new Agent for Formation-Damage Mitigation in Heavy-Oil Reservoir, Core flood experiments result show that biological enzyme with the concentration of higher than 5% can remarkably increase recovery factor for cores with the permeability higher than 1μm2.Simulation experiments of plug removal with biological enzyme for cores with the permeability higher than 1μm2 is more effective than permeability lower of 1μm2.by Combining IFT test with core flood experiments and simulation experiments of plug removal, we can determine the optimum condition for field application of biological enzyme.

2.2.2 Case Study In Sudan:

In 2016 Y.Y. Foo, R.D. Tewari, K.C. Kok, A. Elrufai, H. Elbaloula and L. Elkheir conducted a laboratory evaluation of Chemical EOR Process for Viscous and High EACN Oil in East African Oilfields , the result shows The optimum ASP concoction was formulated at alkaline Na2CO3 concentration of 0.5 wt.%, surfactant S6 concentration of 0.2 wt.% and polymer P1 concentration of 0.2 wt.%,with additional brine

(NaCl) salinity of 3000 ppm , ASP flooding had increased the final oil recovery factor up to 62 and 54 % OOIP and The reduction of residual oil saturation was estimated to be 47 % and 35 % of Sorw.

In 2016 HaythamA.Mustafa , Ali Faroug , EnasMukhtar , Leksono , Mucharam , HushamElblaoula , BadreldinA.Yassin , FadulAbdalla and Tagwa Musa studied Implementation of chemical EOR as Huff and Puff to improve Oil recovery for heavy Oil Field by Chemical Treatment (SEMAR) Case Study Bamboo Oil Field-Sudan , the result show that combinations of micro emulation effect , imbibitions effect and oil viscosity reduction from 76 cp to 2 cp will improve PI significantly ,

Incremental from BBW 27 max 895 bopd, cumulative 3427bbl oil, average 857 bopd for 4 days. Incremental from BBW 13 max 263 bopd, cumulative 975bbl oil, average 45 bopd for 22 days. Incremental from BBW 14 max 108 bopd, cumulative 2268bbl oil, average 87 bopd for 26 days. Incremental from BBW 17 max 256 bopd, cumulative 1074bbl oil, average 37 bopd for 29 days. Incremental from BBW 22 max 551 bopd, cumulative 6183bbl oil, average 177 bopd for 35 days. Incremental from BBW 25 max 165 bopd, cumulative 3265bbl oil, average 63 bopd for 52 days.

In 2015 Husham Ali studied Chemical Enhanced Oil Recovery Pilot Design for Heglig Main Field-Sudan, The results show that a combination of 0.4wt% of Alkaline, 0.1wt% of Surfactant, and 0.1wt% of Polymer in an ASP flooding process can increase the recovery factor of Heglig main up to 43.54%.

Many studies have been conducted to Enzyme – Enhanced Oil Recovery around the world, the studies included laboratory experiments (core flooding), field application, and analysis research.

This thesis is the first graduation project in Sudan to study the EEOR.

The Thesis analyses and evaluate the results of core flood experiment done using Greenzyme for a Sudanese oilfield (hamra-east) , to predict the performance of greenzyme in Sudanese wells and to determine the effect of the enzyme on recovery factor.

Chapter Three: Methodology

3.1 introduction:

The reservoir data (temperature , pressure, porosity ,permeability ,depth) and fluid properties (viscosity ,density) had been collect from laboratory core flood experiment for core samples taken from Hamra-East filed , to establish simulation model through CMG software in order to predict the effect of biochemical agent (greenzyme) in production rate , recovery factor and produce water (WC) .

3.2 Computer Modeling Group

Abbreviated as CMG, is a software company that produces reservoir simulation programs for the oil and gas industry. It is based in Calgary, Alberta, Canada with branch offices in Houston, Dubai, Caracas and London. The company is traded on the Toronto Stock Exchange under the symbol CMG. The company offers three simulators, a black oil simulator, called IMEX, a compositional simulator called GEM and a thermal compositional simulator called STARS.

The company began in 1978 as an effort to develop a simulator by Khalid Aziz of the University of Calgary's Chemical Engineering department, with a research grant from the government of Alberta. A commercial product was being sold by the late 1980s. For the first 19 years of the company's history it was a non-profit entity. In 1997 it became a regular public company when it was listed on the TSX. The company now claims over 400 clients in 49 countries.

Today, CMG remains focused on the development and delivery of reservoir simulation technologies to assist oil and gas companies in determining reservoir capacities and maximizing potential recovery.

3.3 CMG components:

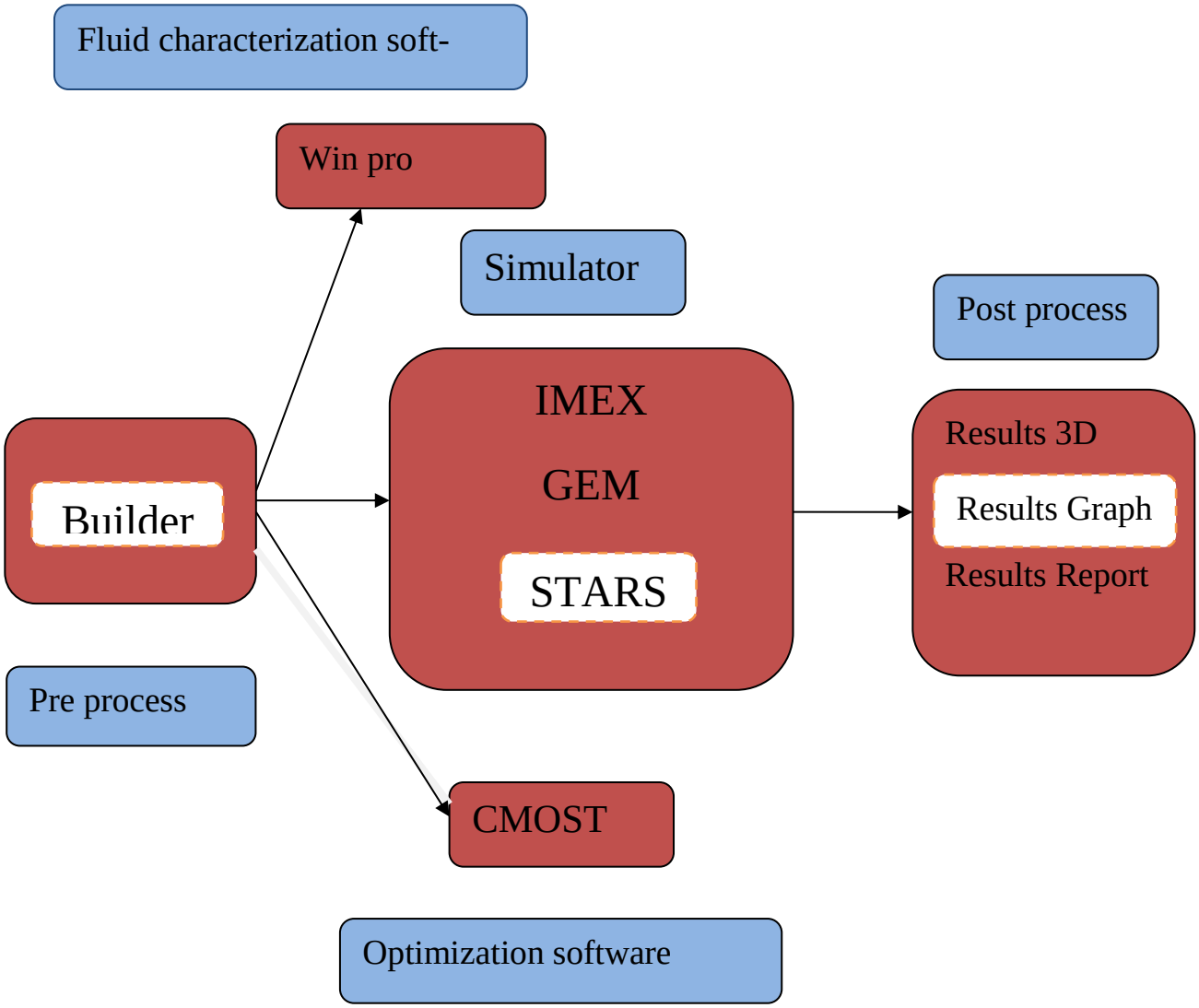


Figure 3-1 : CMG Components

3.3.1 Builder :

Builder, a Windows-based application, helps engineers create input files for CMG reservoir simulators – IMEX, GEM, STARS. Through the use of 2D and 3D visualization, and efficient keyword input, Builder helps reservoir engineers realize immediate time savings by efficiently navigating them through the complex process of building reservoir simulation models. Builder simplifies the creation of simulator models by providing a framework for data integration and workflow management between

CMG's reservoir simulators and the "outside world". Its intuitive interface and numerous process wizards make reservoir simulation accessible to all organizations, even those with limited modeling experience.

3.3.2 STARS -Thermal & Advanced Processes Reservoir Simulator:

STARS is the undisputed industry standard in thermal and advanced processes reservoir simulation. STARS is a thermal, k-value (KV) compositional, chemical reaction and geomechanics reservoir simulator ideally suited for advanced modeling of recovery processes involving the injection of steam, solvents, air and chemicals. The robust reaction kinetics and geomechanics capabilities make it the most complete and flexible reservoir simulator available

3.3.3 IMEX - Three-Phase, Black-Oil Reservoir Simulator :

IMEX, one of the world's fastest conventional black oil reservoir simulators is used to obtain history-matches and forecasts of primary, secondary and enhanced or improved oil recovery processes. In addition, IMEX models production from conventional sandstone and carbonate reservoirs, including the effects of natural fractures and is widely used to model primary production of gas and liquids from hydraulically fractured shale and tight sand reservoirs.

3.3.4 GEM - Compositional & Unconventional Oil & Gas

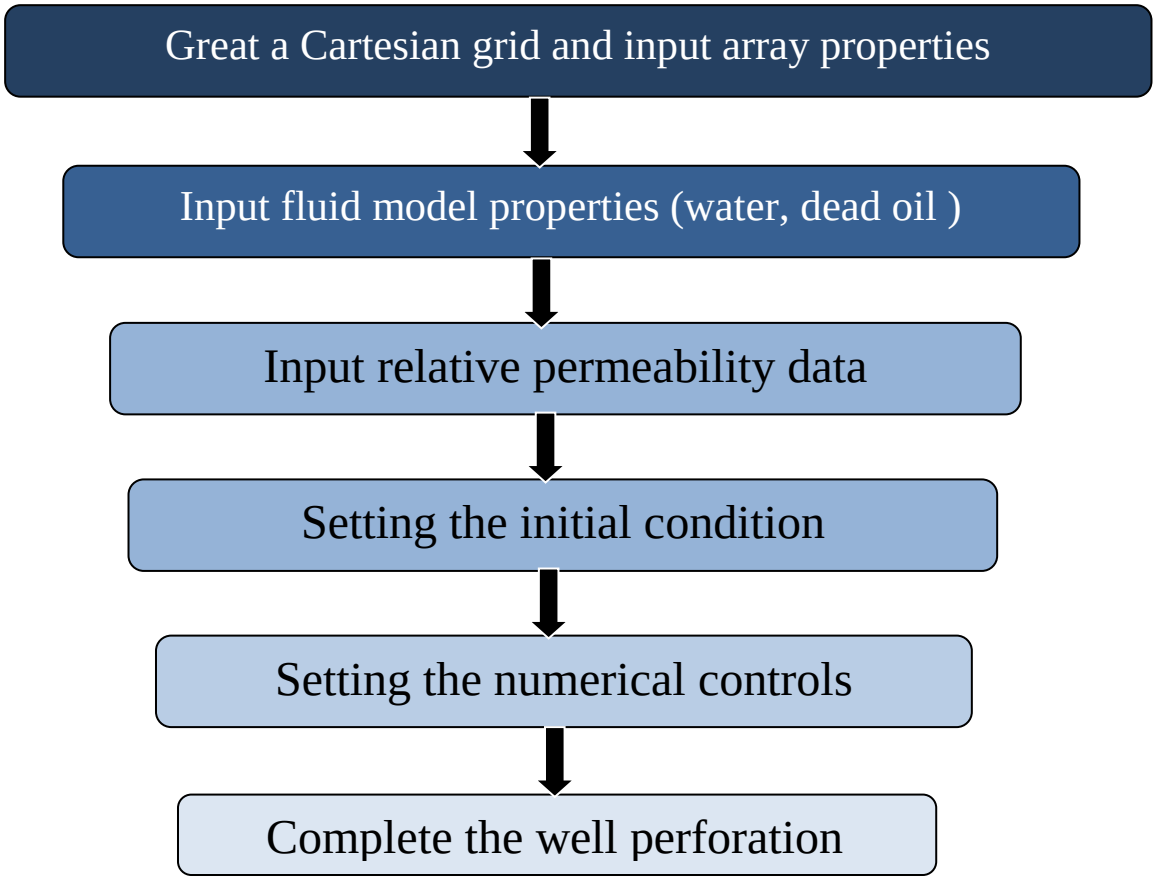
GEM is the world’s leading reservoir simulation software for compositional and unconventional modeling. GEM is an advanced general Equation-of-State (EOS)compositional simulator that models the flow of three-phase, multi-component fluids. GEM can model any type of recovery process where effective fluid composition is important.

3.3.5 RESULTS - Visualization & Analysis :

Through industry-leading visualization capabilities, results allows engineers to enhance productivity, gain new understanding and insight into recovery processes and improve Net Present Value (NPV). Results, a set of post-processing applications, is designed to visualize and report CMG software – STARS, GEM, IMEX – input and output data into 2D aerial maps, 2D cross-sections, 3D perspectives, stereoscopic 3D formats and tabular reports. Results is comprised of three modules : Results 3D,Results Graph, and Results Report.

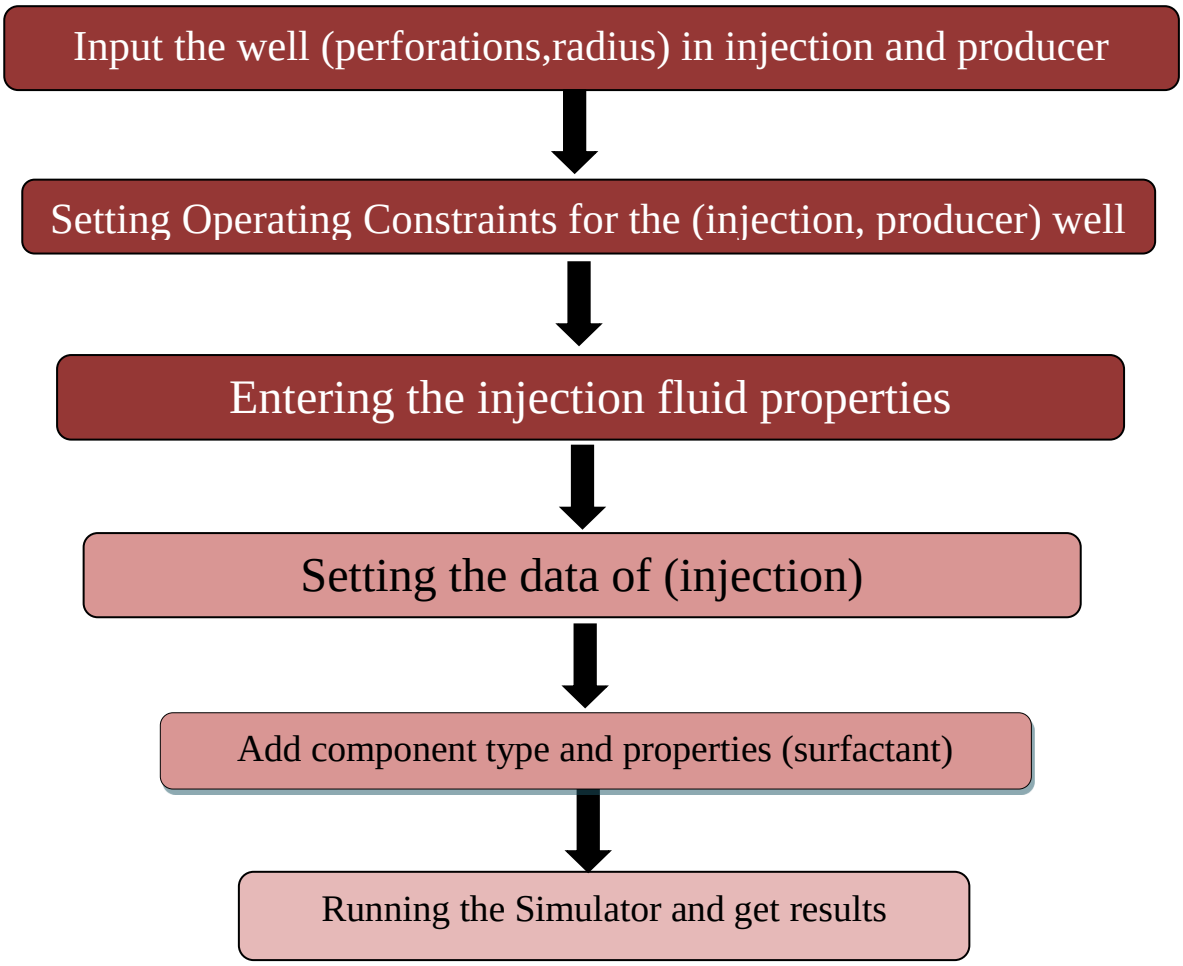
3.4 Building Core Flood Simulation Model In STARS:

Flow chart below represents the steps of creating the numerical model through the use of CMG software:



Flow Chart 3-1 : Steps of Building The Numerical Model

Building the core flood will be by following the flow chart below:



Flow Chart 3-2 : Steps of Building Core Flood Stimulation

Setting Operating Constraints for the injection well, input injection fluid and click apply

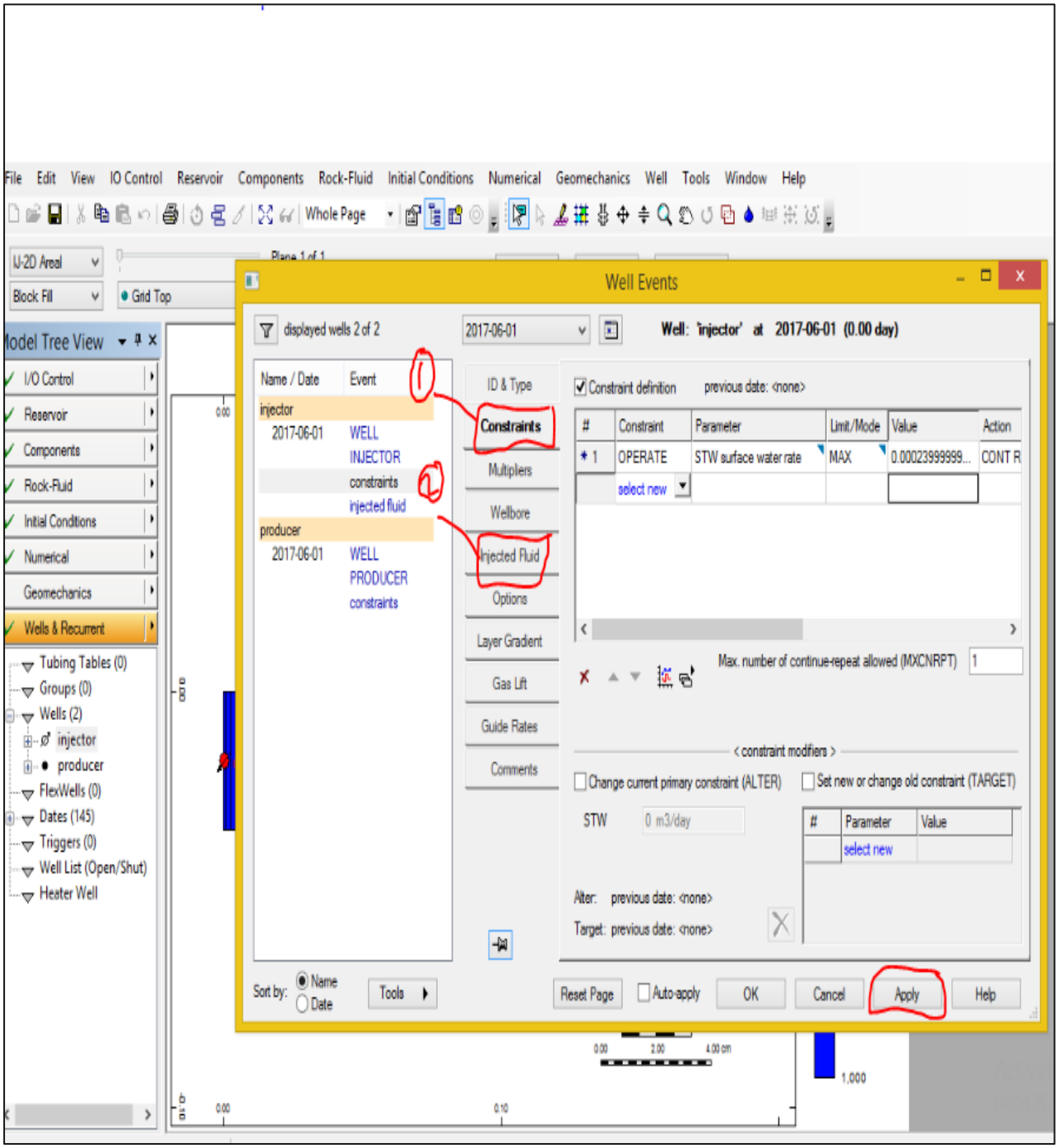


Figure 3-2: Injection Well Constrains

Setting Operating Constraints for the production well and click ok

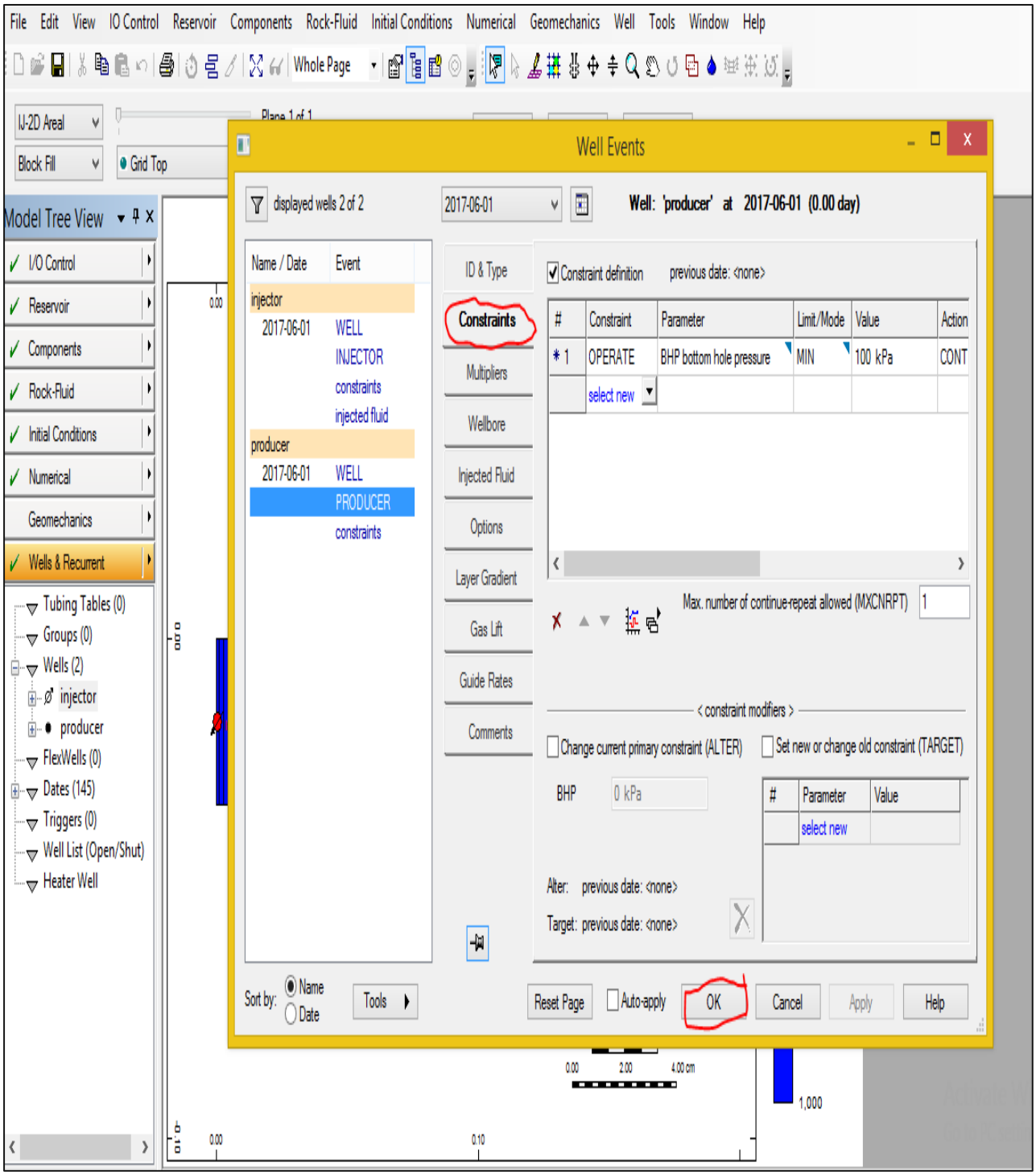


Figure 3-3: Injection Well Constrains

Input the chemical component from process wizard and sett and click next

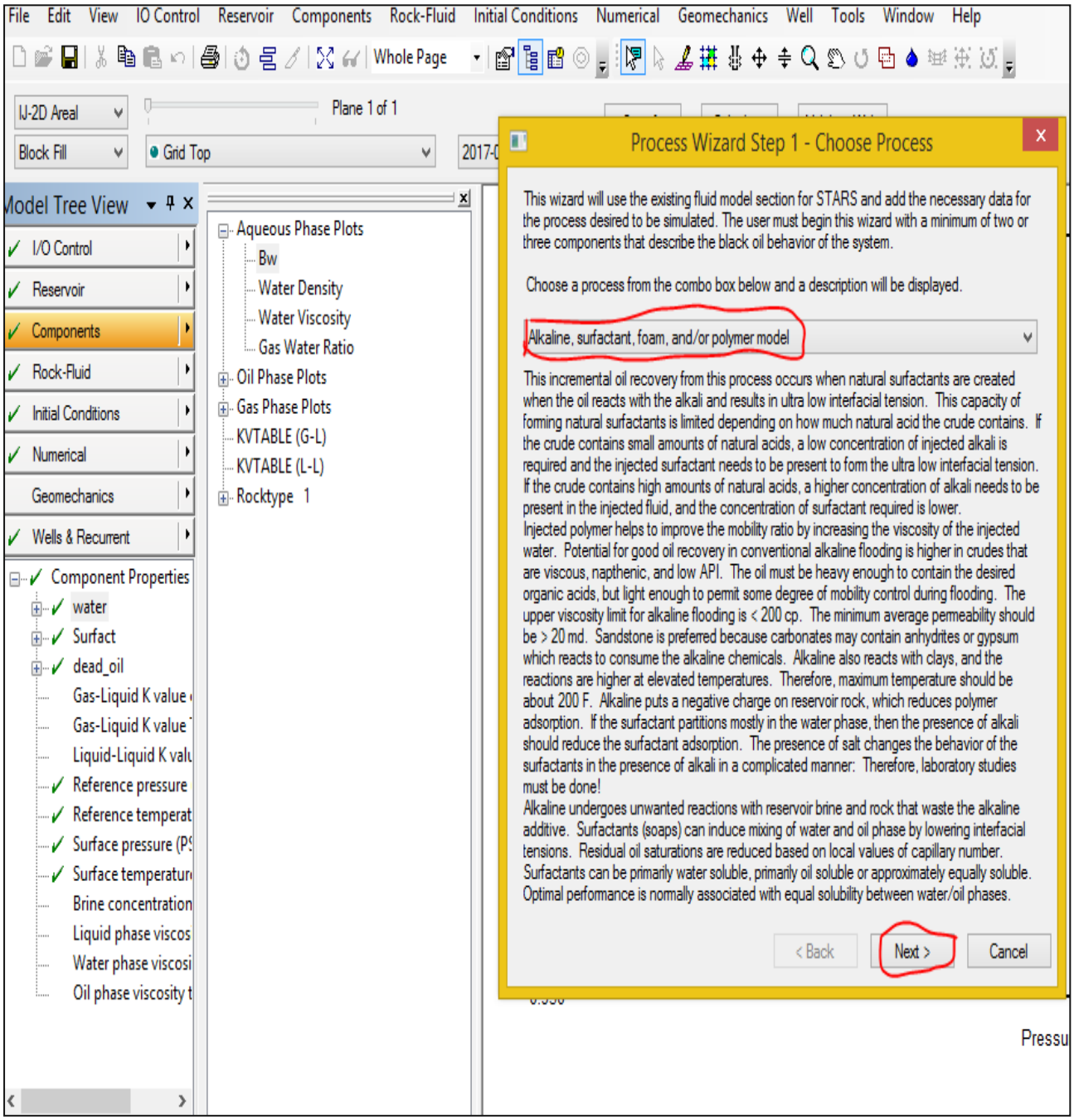


Figure 3-4: Chemical Component

Then select one component (surfactant) and click next

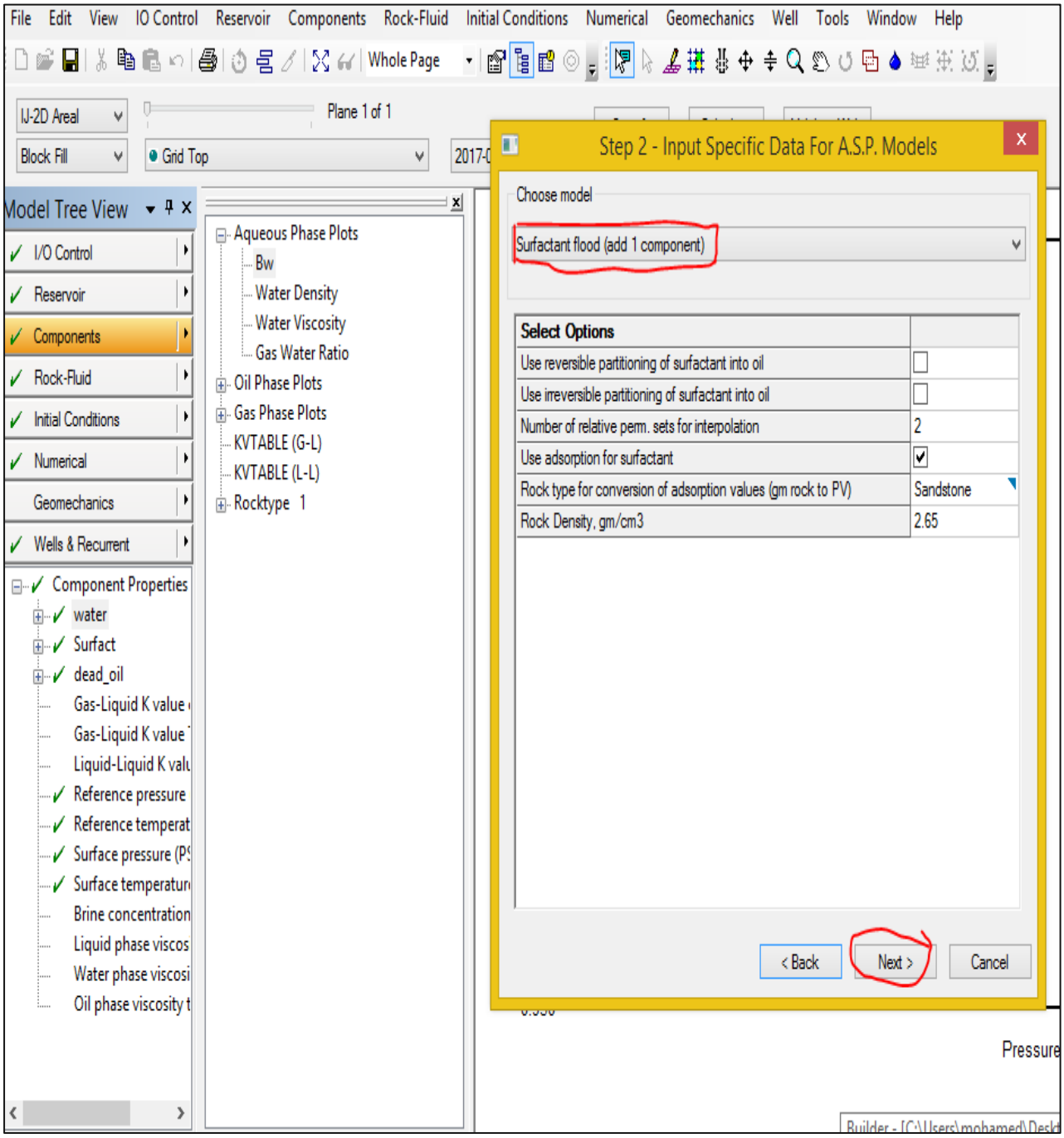


Figure 3-5: Selecting Surfactant

Input interfacial values and click next

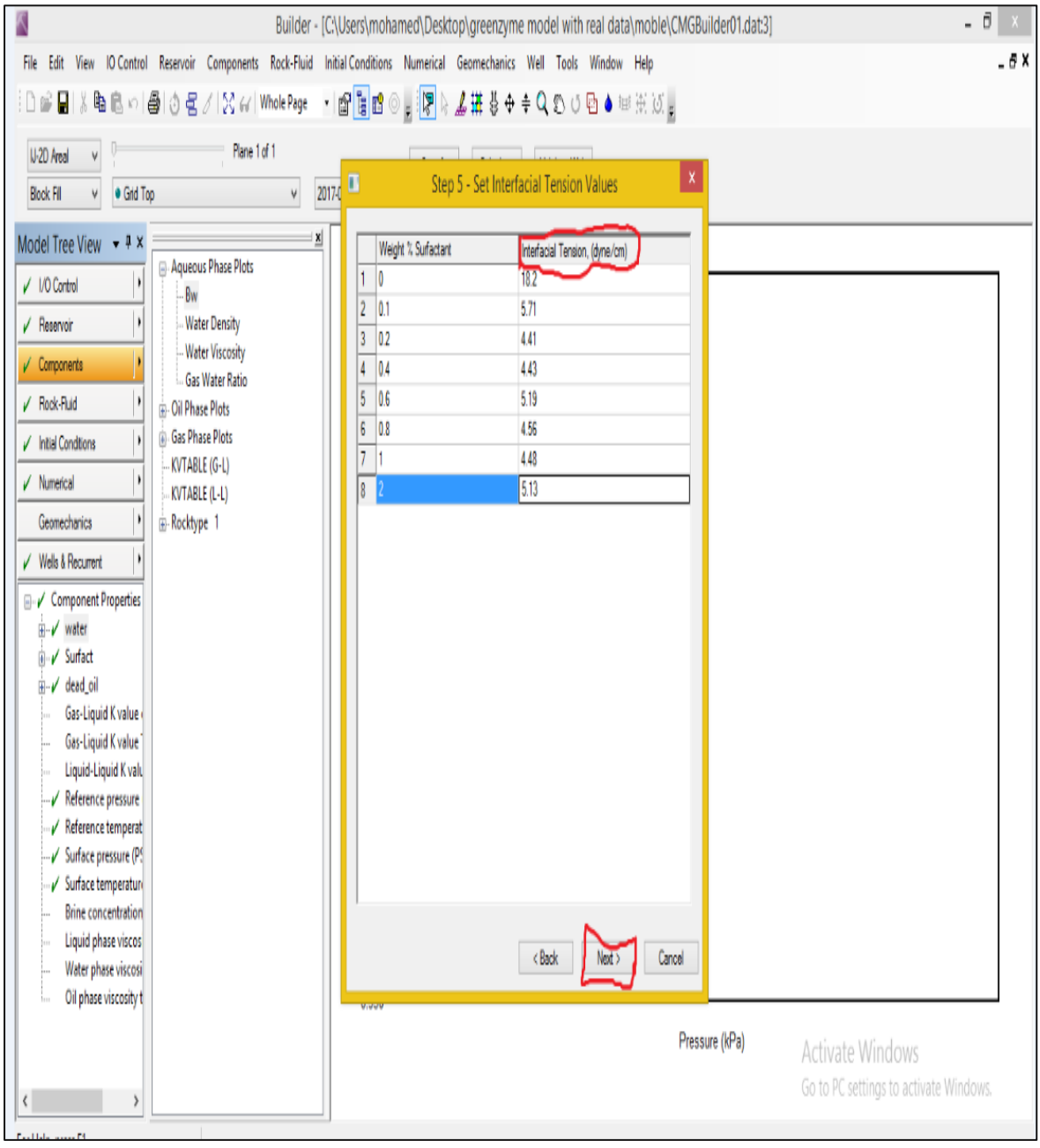


Figure 3-6: Interfacial Tension Values

Add the range of date fore water and surfactant flooding and click close

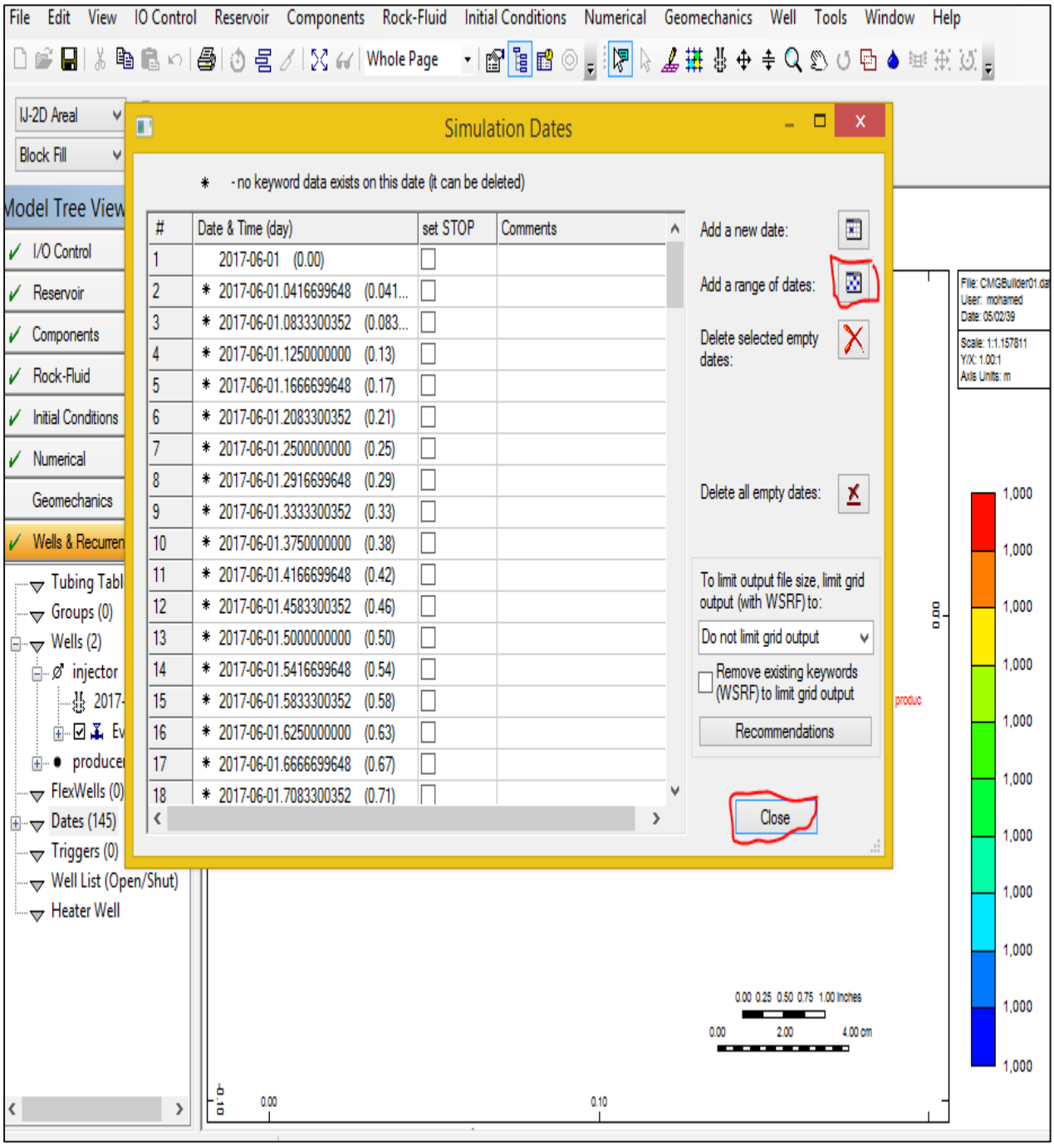


Figure 3-7: Date configuration

Final step run the model

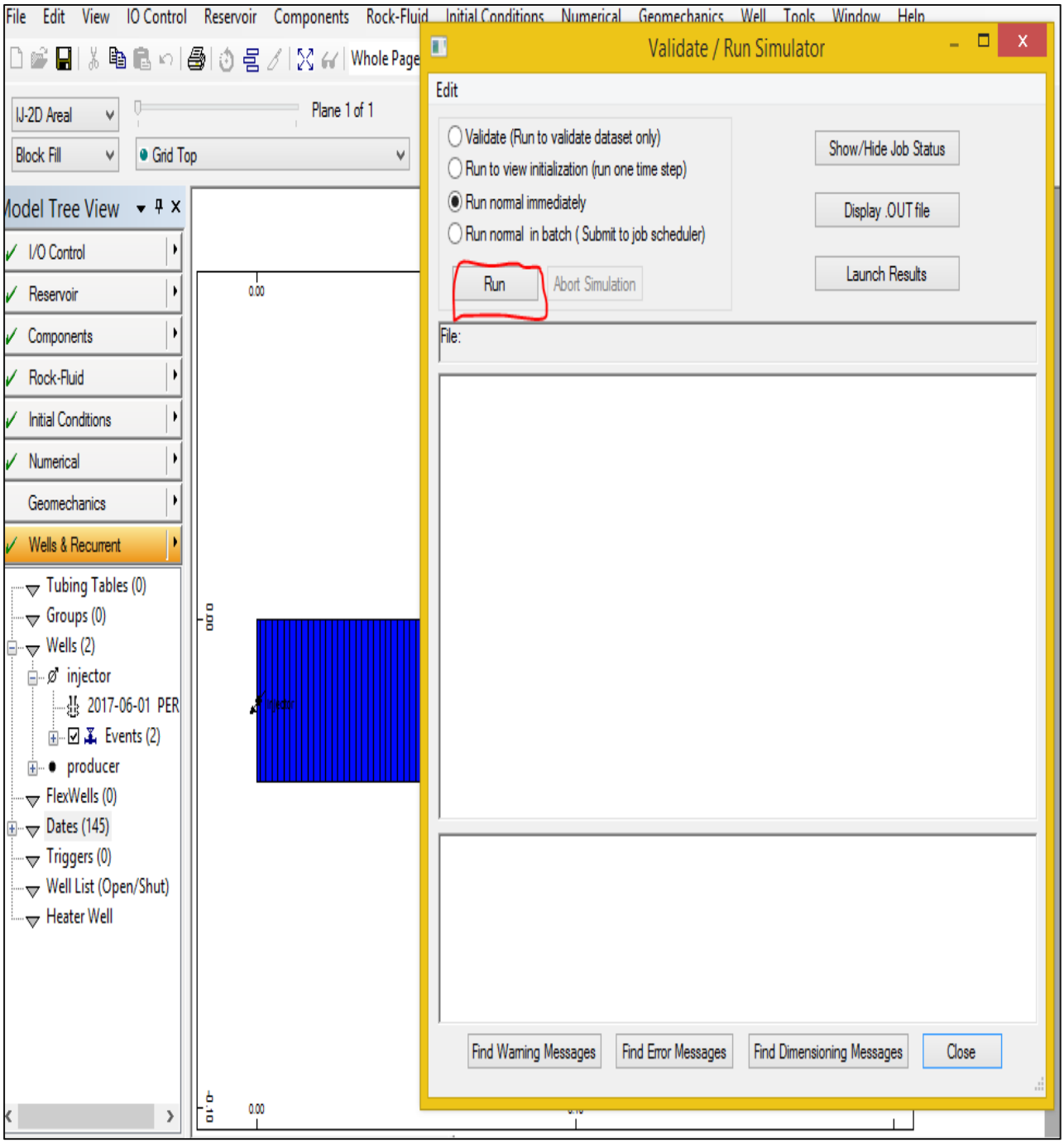


Figure 3-8: Running the model

Chapter Four: Results and Discussion

4.1 Introduction:

Hamra East 8 well is located in Block 2B South Kordufan was put to productionin January 2012 ,well is producing from Aradeiba-D,Aradeiba-D1,Aradeiba –E,Aradeiba –F, water injection pilot started in November 2015

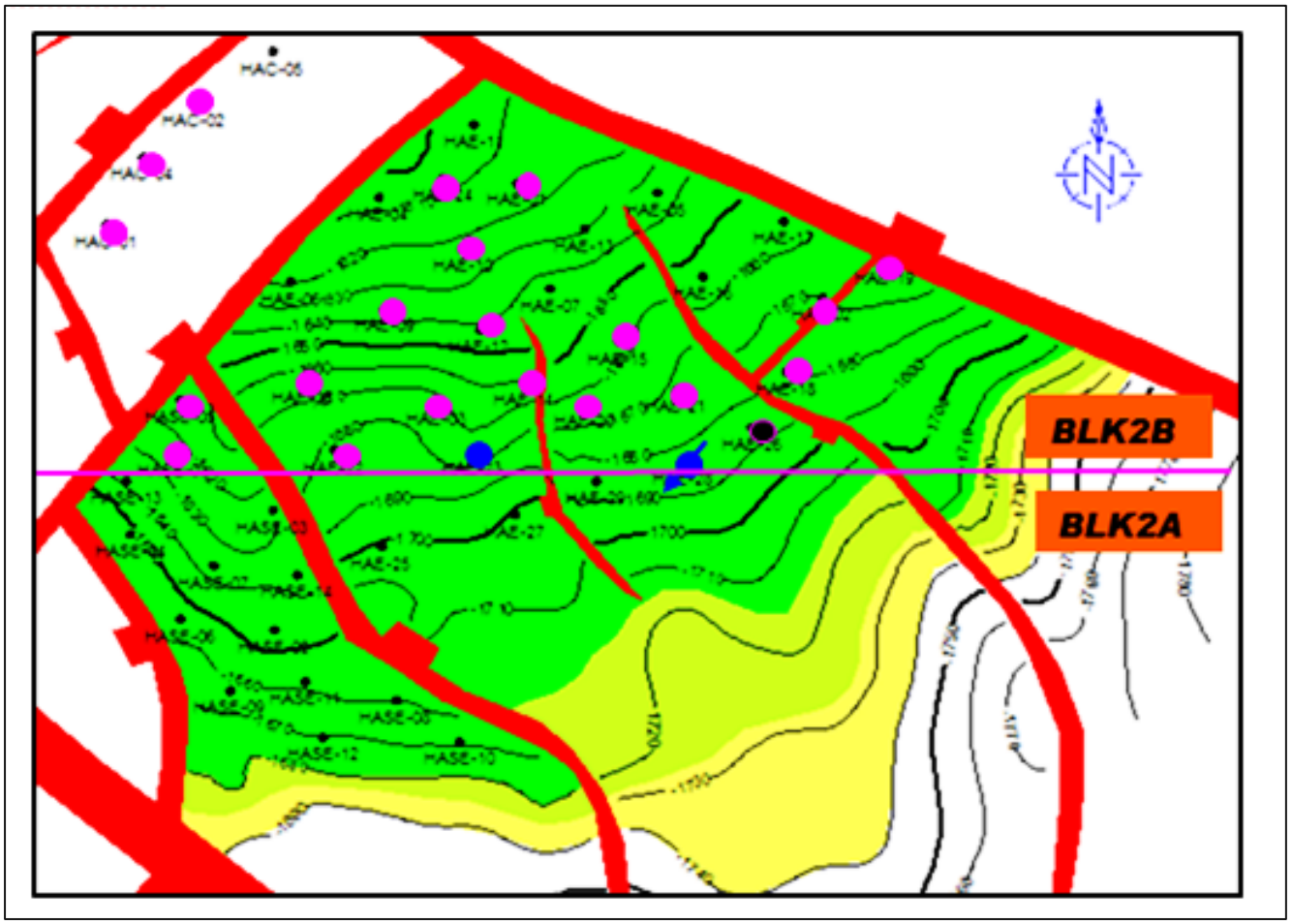


Figure 4.2Well No. 8 Location Map

4.1.1 Reservoir Properties :

Table (4-1) General Properties of Hamra Cluster 2B Structures

Reservoir	STOIIP	RF	EUR	Production		Reserves (2P)		Potential
	2P	(%)	@Dec-2031	2017.1-4	Cum	DEV	UNDEV	Recovery
Hamra Central	24.09	5.7	1.38	0.04	1.09	0.29	0	0
Hamra East	73.34	27.3	20.01	0.44	13.02	5.14	1.85	0
Hamra Southeast	4.98	50.6	2.52	0.09	1.23	1.29	0	0
Total (MMB)	**102.41**	**23.3**	**23.90**	**0.57**	**15.34**	**6.71**	**1.85**	**0**

Table (4-2) Numbers of Wells In The Three Structures

Structures	Total Wells	Wells Status			Completion Types		
		Active Producers	Active In-jectors	Idle Wells	Vertical Wells	Deviated Wells	Horizontal Wells
Hamra E	26	23	0	3	25	1	/
Hamra SE	2	2	/	/	2	/	/
Hamra C	5	4	/	1	5	/	/
Total	33	29	0	4	32	1	0

Table (4-3) Shows The Density And Viscosity of Reservoir Fluid

Item	**Unit**	
Density	g/cm3	0.8273
Viscosity	m.pa.s	4.7

4.2 Laboratory Data:

Table (4-4) Shows The Basic Properties of The Selected Samples

Well	Sample no .	Sample depth (m)	Sample length (cm)	Sample diameter (cm)	Bulk volume	Porosity %	Permeability (md)	Pore volum (cc)
Hamra east-3	2	1688	6.325	3.882	74.86	26.6	330.6	19.9
Hamra east-3	7	1690	6.840	3.879	80.82	23	101.9	18.6
Hamra east-3	15	1671	7.228	3.882	85.53	25.2	401.1	21.4

Table (4. 5) Experimental Operational Conditions

Model	Pore pressure (Psi)	Overburden pressure (Psi)	Reservoir tem-perature (c)
HE-2	1260	2700	72.2
HE-7	1260	2700	72.2
HE-15	1260	2700	72.2

4.3 Comparison between lab and field implementation.

Experimental Core Flooding:

- This analysis has been done to evaluate a Greenzyme core flood laboratory experiment done for core samples that have been taken from Hamra East, Hamra East well No: 008.

- From IFT measurements it have been found that for low or high Greenzyme concentration from 0.1 to 15% there is no high change in IFT measurement values so the acceptable Greenzyme solutions concentration for core flooding ranging from 0.1~1%.

- From differential pressure measurements it have been observed that Greenzyme solution with concentration beiger than 0.4% not recommended for field implementation due to the plugging of the three core sample model under reservoir conditions.

- The core flood run for the 3 core samples had successfully increased the RF and reduced the Sor , the reduction in Sor value was 3.1% , 2.01% and 1.67% for 1st , 2nd and 3rd core sample respectively , and that doesn't exceed the Key Performance Indicator (KPI) minimum of 10% reduction of Sor.

Field Implementation:

- The greenzyme injection was implemented in Hamra field in two wells (well He -22, well HAE-24).
- The well HE-22 showed significant performance improvement with Oil Incremental of 45%.
- But the well HAE-24 showed strange performance with oil decrement of 19%.

Since the core flooding modeling hasn't been done for this study before pilot implementation so the thesis will focus on the modeling.

4.4 Effect of Biochemical Agent (Greenzyme):

The concept of greenzyme is to reduce interfacial tension between oil and water So recovery increase and water cut decrease significantly.

Evaluation study was conducted by simulating laboratory core flood experiment to determine the effect of greenzyme – in the three core samples - in the oil rate, cumulative produced oil and water cut, the results are represented in form of curves below:

4.5 Simulating Using CMG :

Figure 4.2 shows the general shape of the CMG software and the Cartesian model of core flooding stimulation for Hamra East_8.

Rock Properties

Click on the " Specify Property " button (top middle of screen) to open the General Property Specification spreadsheet as shown below in Figure 4.3 and enter the data of top grid, grid thickness, permeability (i,j,k), porosity , pressure and temperature .

Relative Permeability

Click the Rock-Fluid tab in the tree view which located on the left side of the screen. Double click on Rock Fluid Types in the tree view. A window will open. Click on the button and select New Rock Type, then entering the relative permeability table as shown in Figure 4.4

The Initial conditions of the reservoir

Click the Initial conditions on the tree view of Builder. Double click on Initial Conditions. Then click on do not perform vertical equilibrium calculations as shown on figure 4.5

Injected fluid properties

Click on the "Well & Recurrent" on the tree view of Builder. And clicking on the "Wells", where there is two wells .Double clicking on the injection well and then go to "Injected fluid" enter the water and surfactant composition as 0.9 , 0.1 respectively as in Figure 4-6

Figure 4-7 shows the perforations for injection well while figure 4-8 shows the perforations for production well.

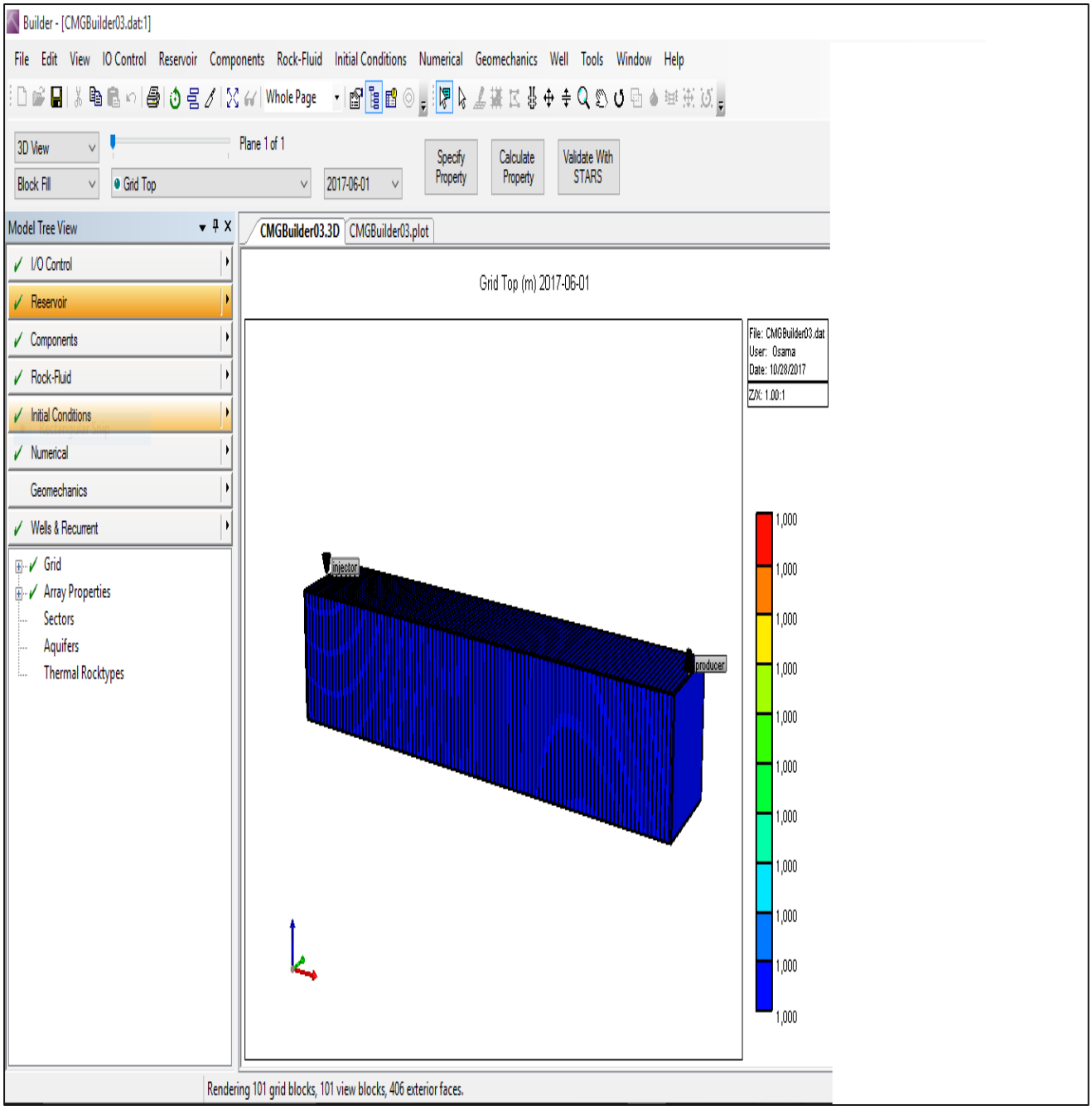


Figure 4-2 General Shape of the CMG Software

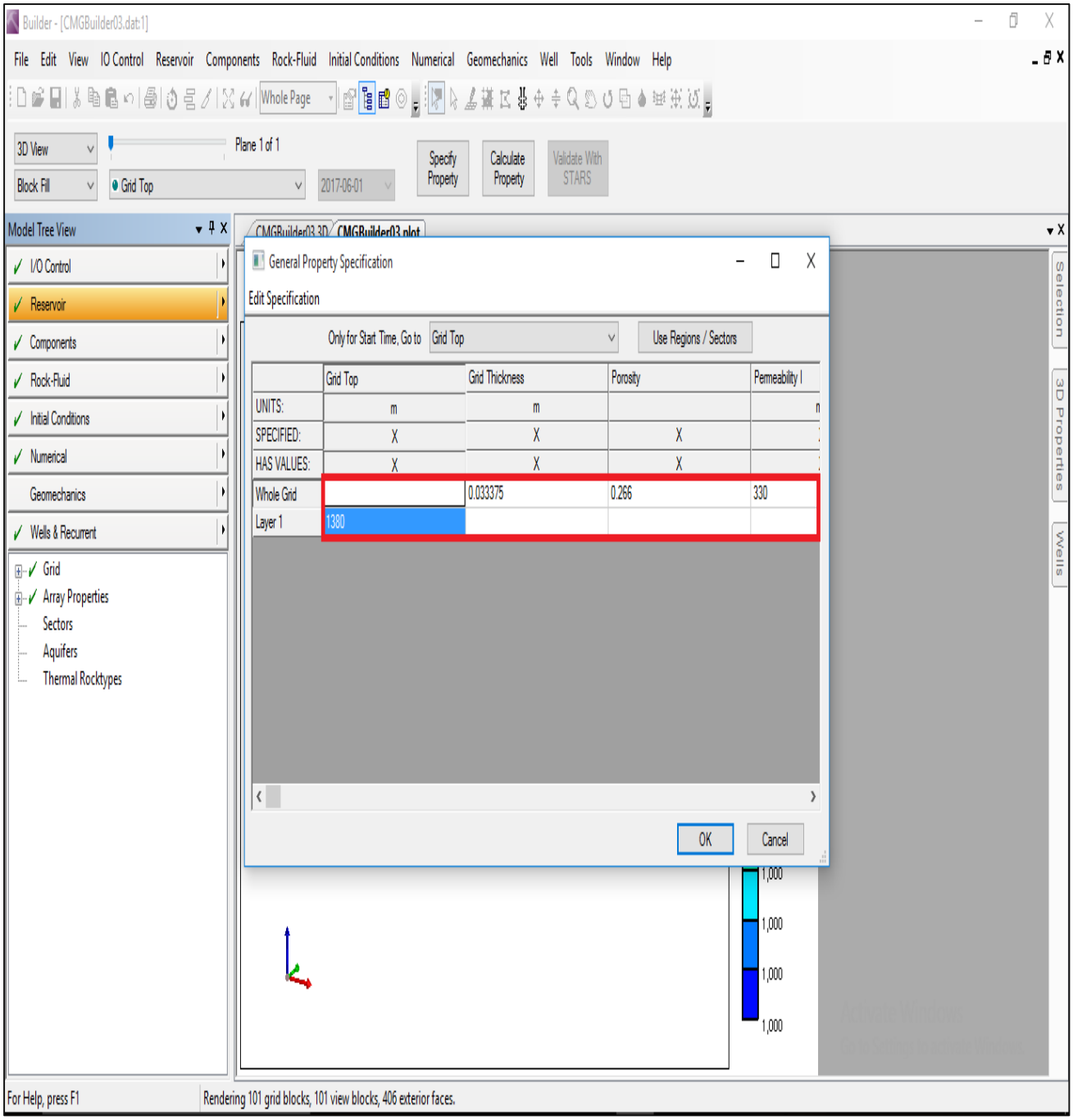


Figure 4-3: Core Properties

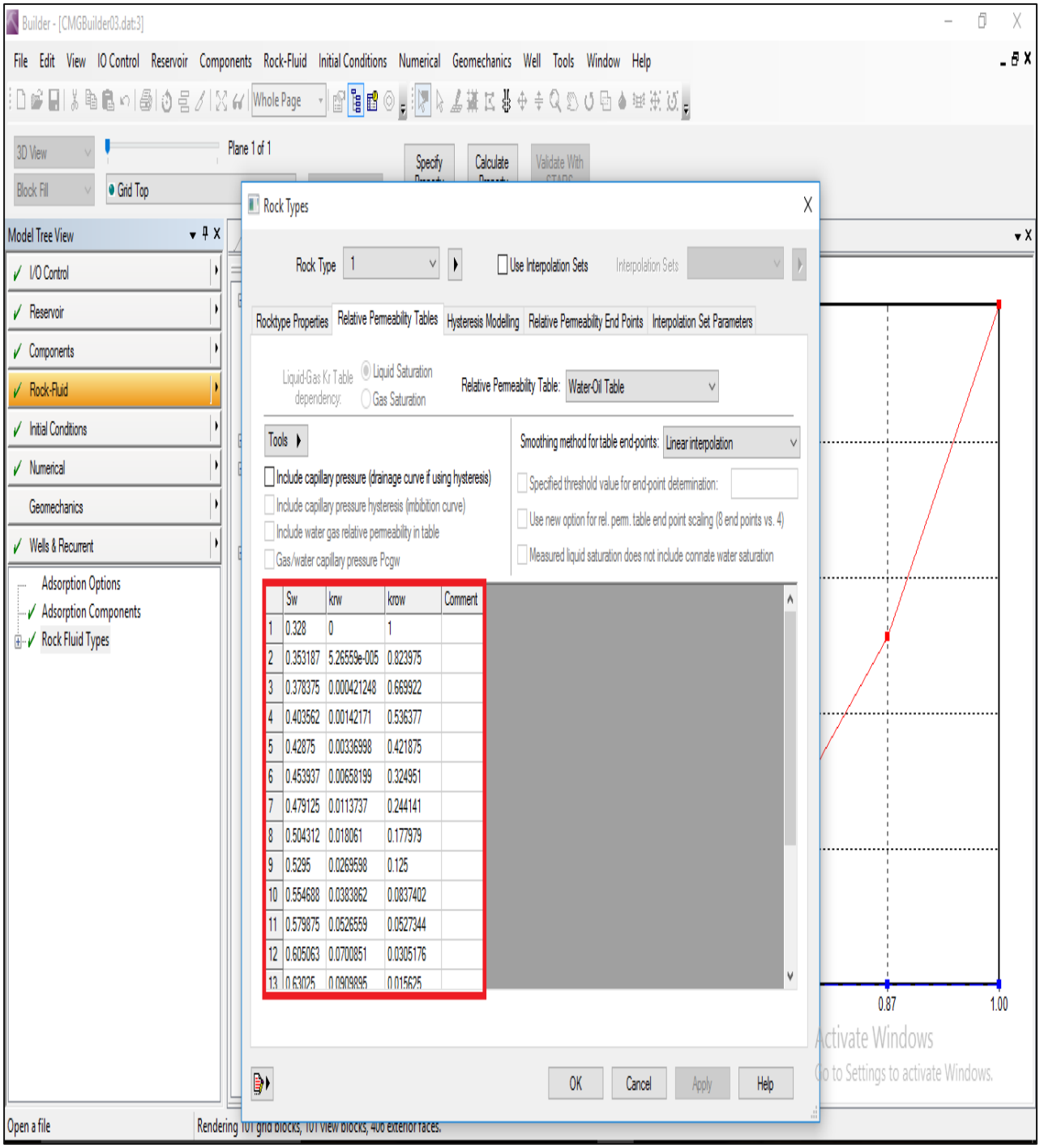


Figure 4-4: Relative Permeability Table

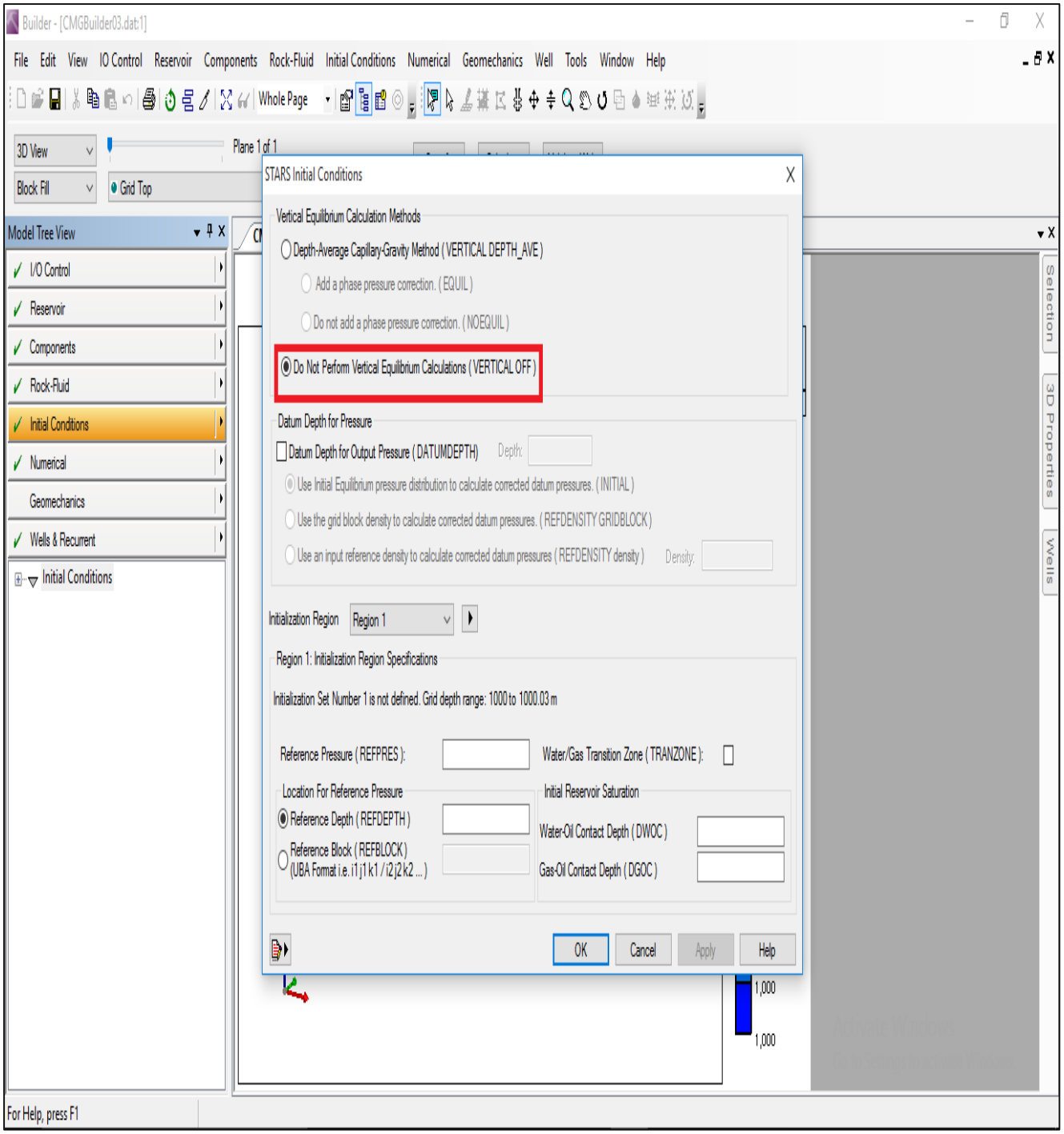


Figure 4-5: Initial Condition of The Reservoir

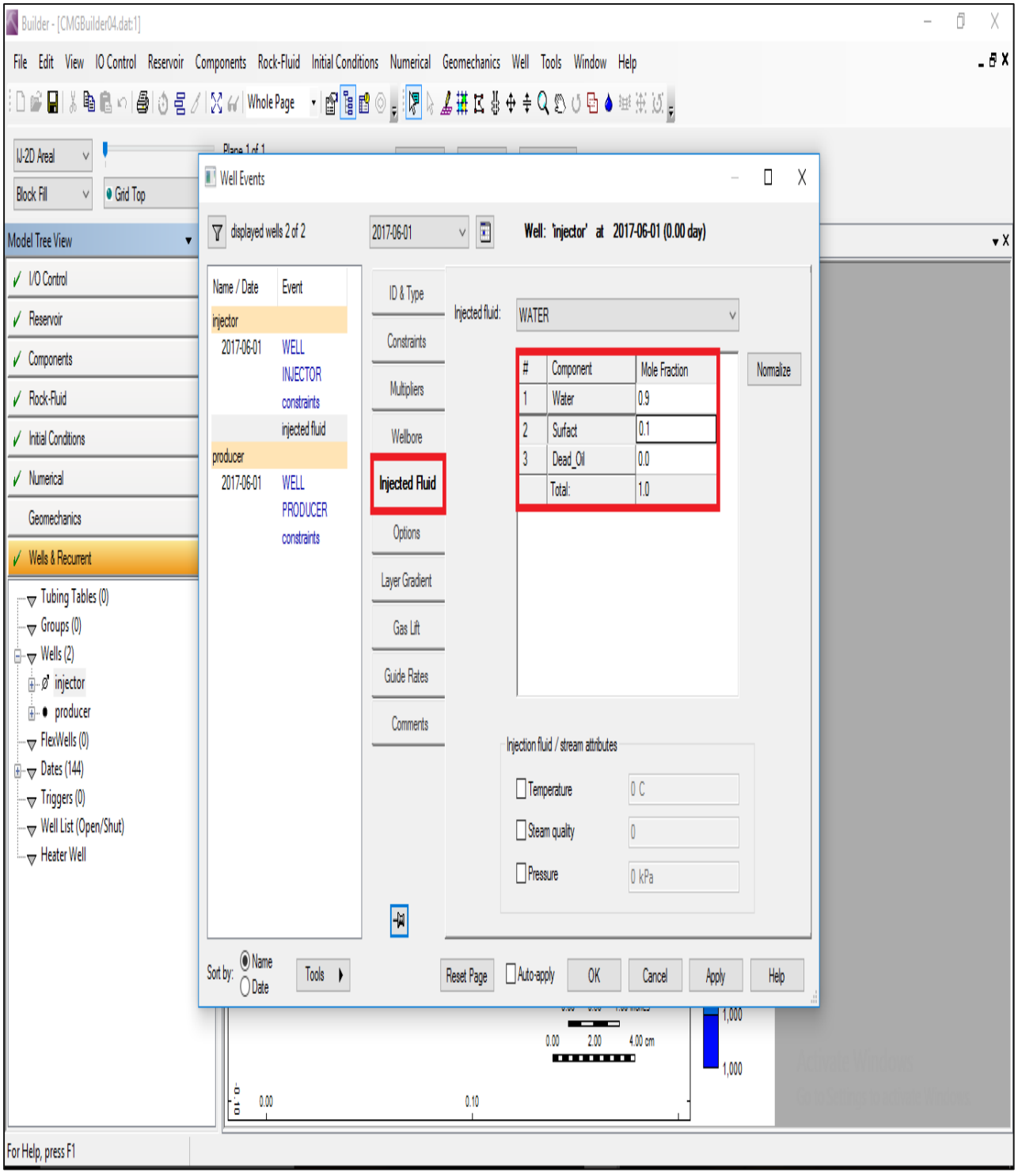


Figure 4-6: Injected Fluid Properties

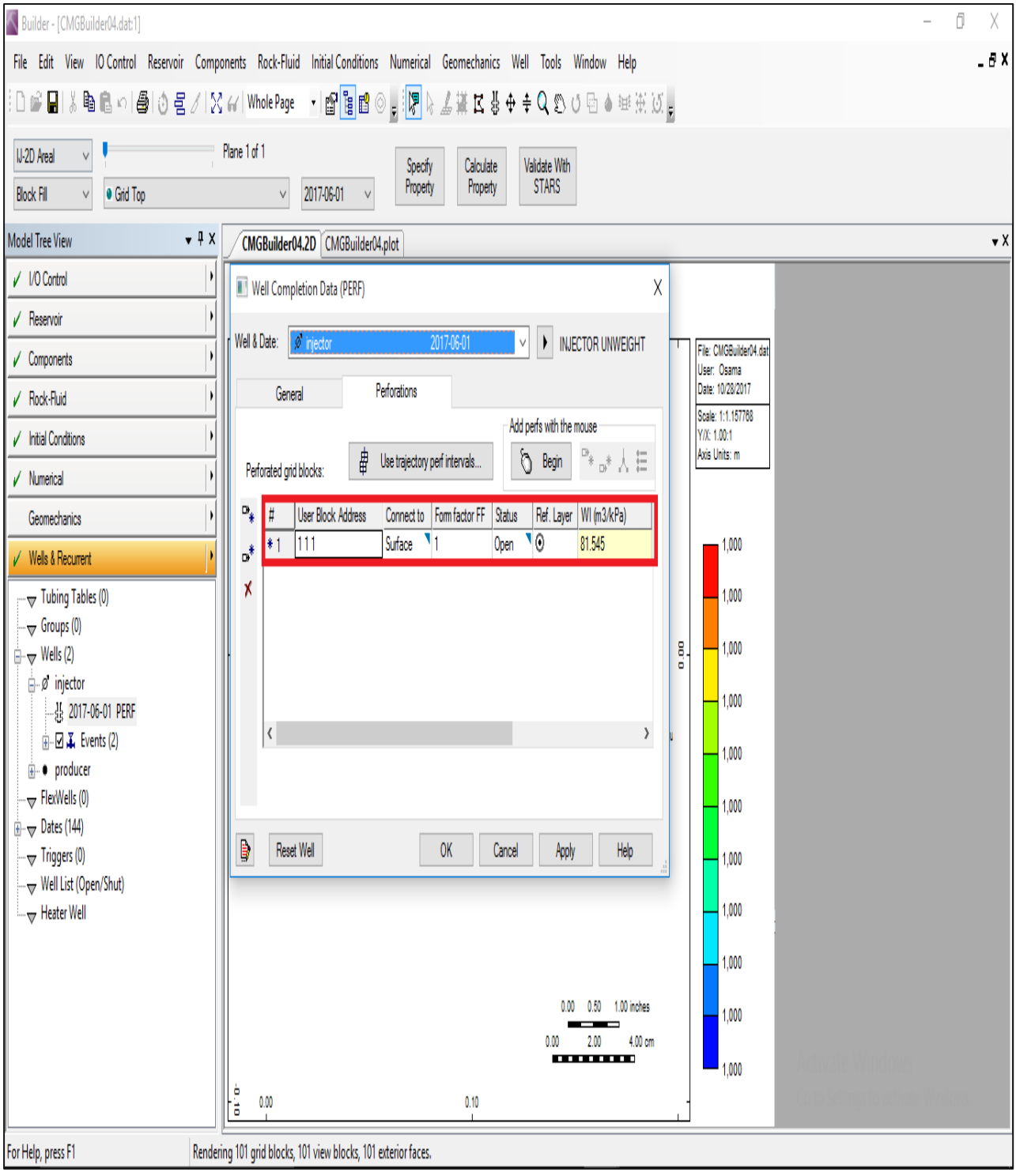


Figure 4-7: Perforation for Injection Well

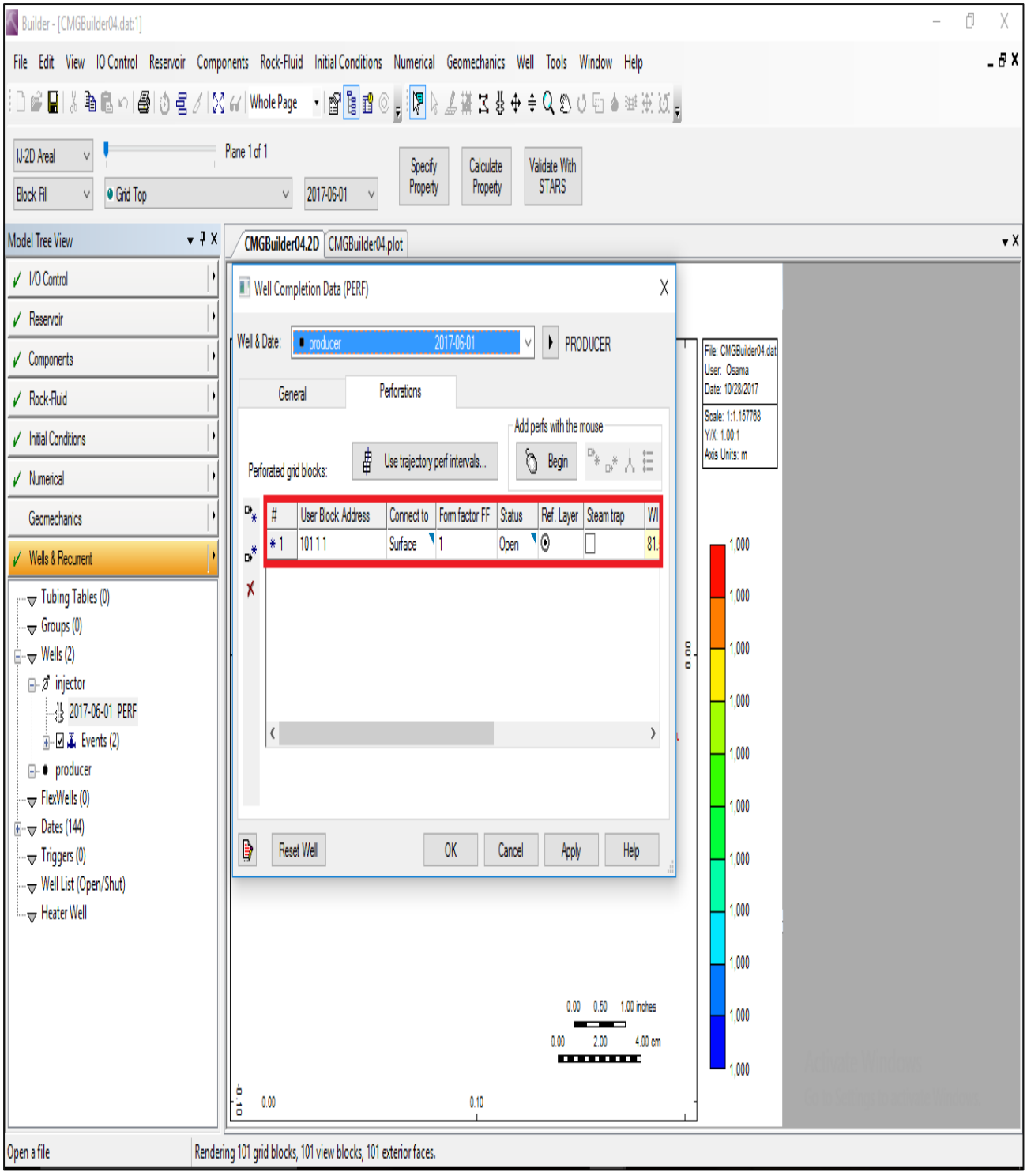


Figure 4-8: Perforation For Production Well

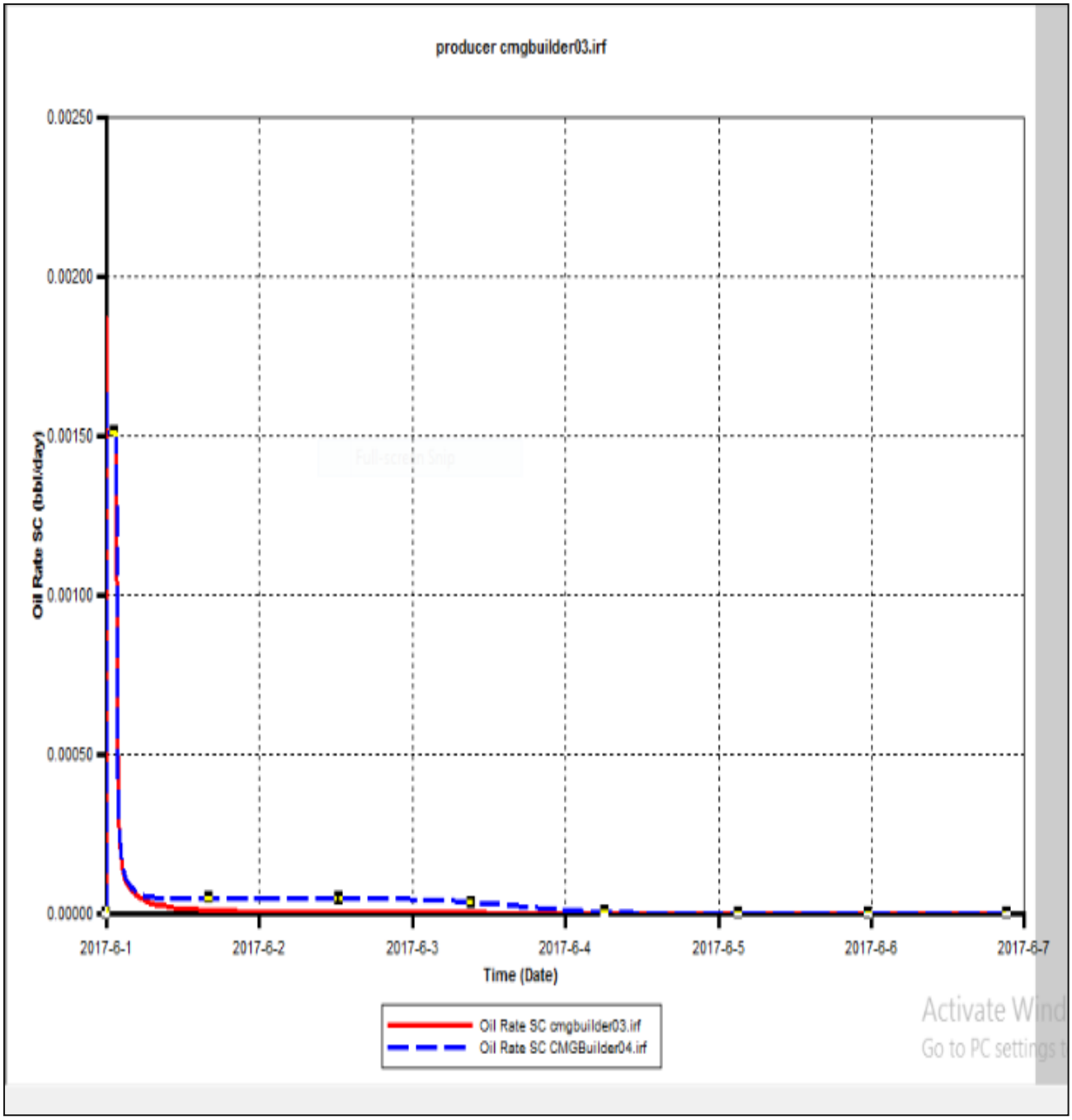


Figure 4-9: Comparison Between oil Rate Ofcore-002 (Greenzyme Flooding And Water Flooding)

Using Greenzyme can increase the oil rate almost double from 0.00025726 bbl to 0.00026858 bbl (Figure 4-3) compared to water flooding which is about 4.4% additional oil.

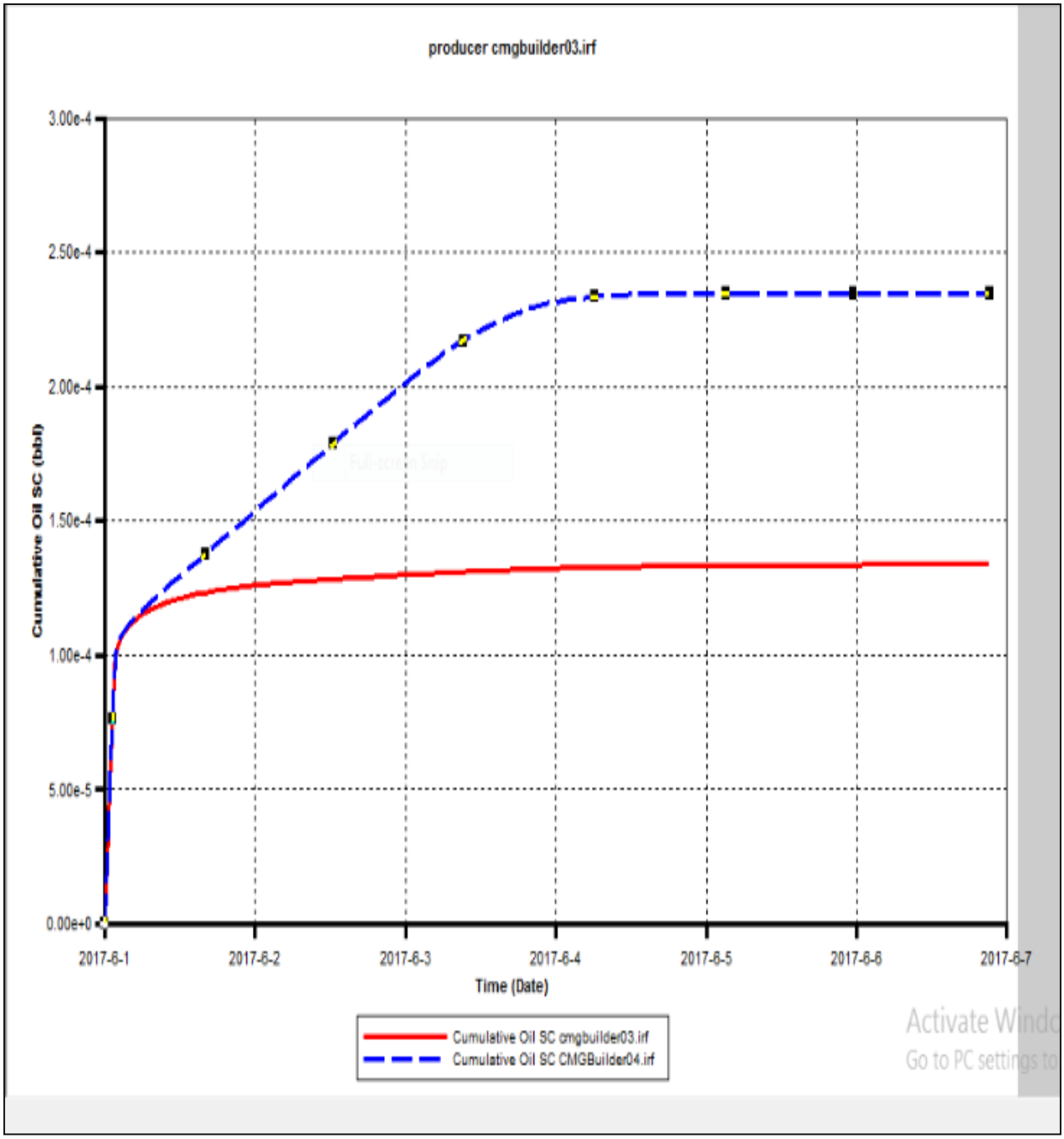


Figure 4-10: Comparison Between Cumulative Oil of Core-002 (Greenzyme Flooding And Water Flooding)

Using Greenzyme can increase the cumulative oil almost double from 0.00084374 bbl to 0.0014766bbl (Figure 4-3) compared to water flooding which is about 75% additional oil.

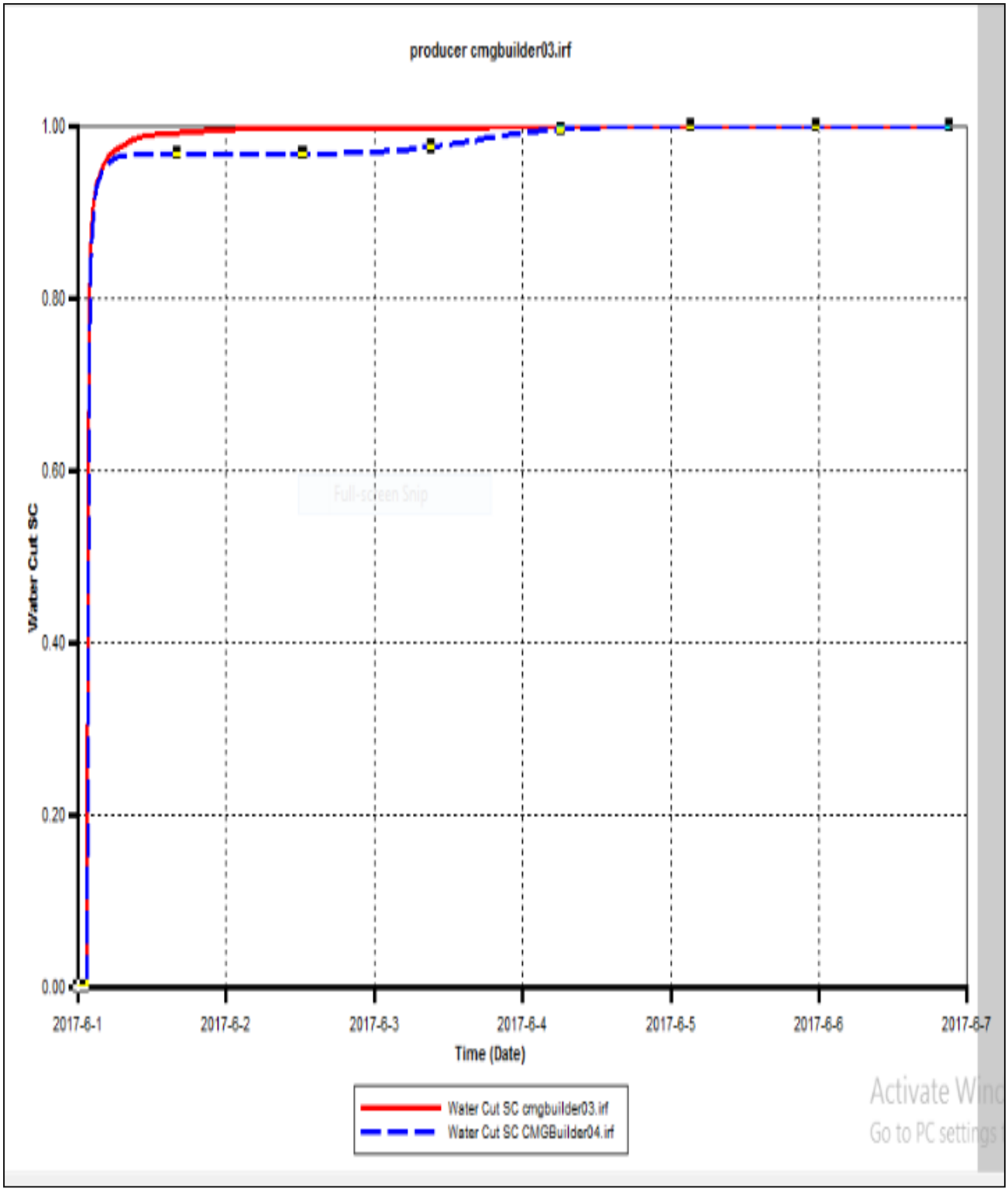


Figure 4-11: Comparison between Water Cut of Core-002 (Greenzyme Flooding and Water flooding)

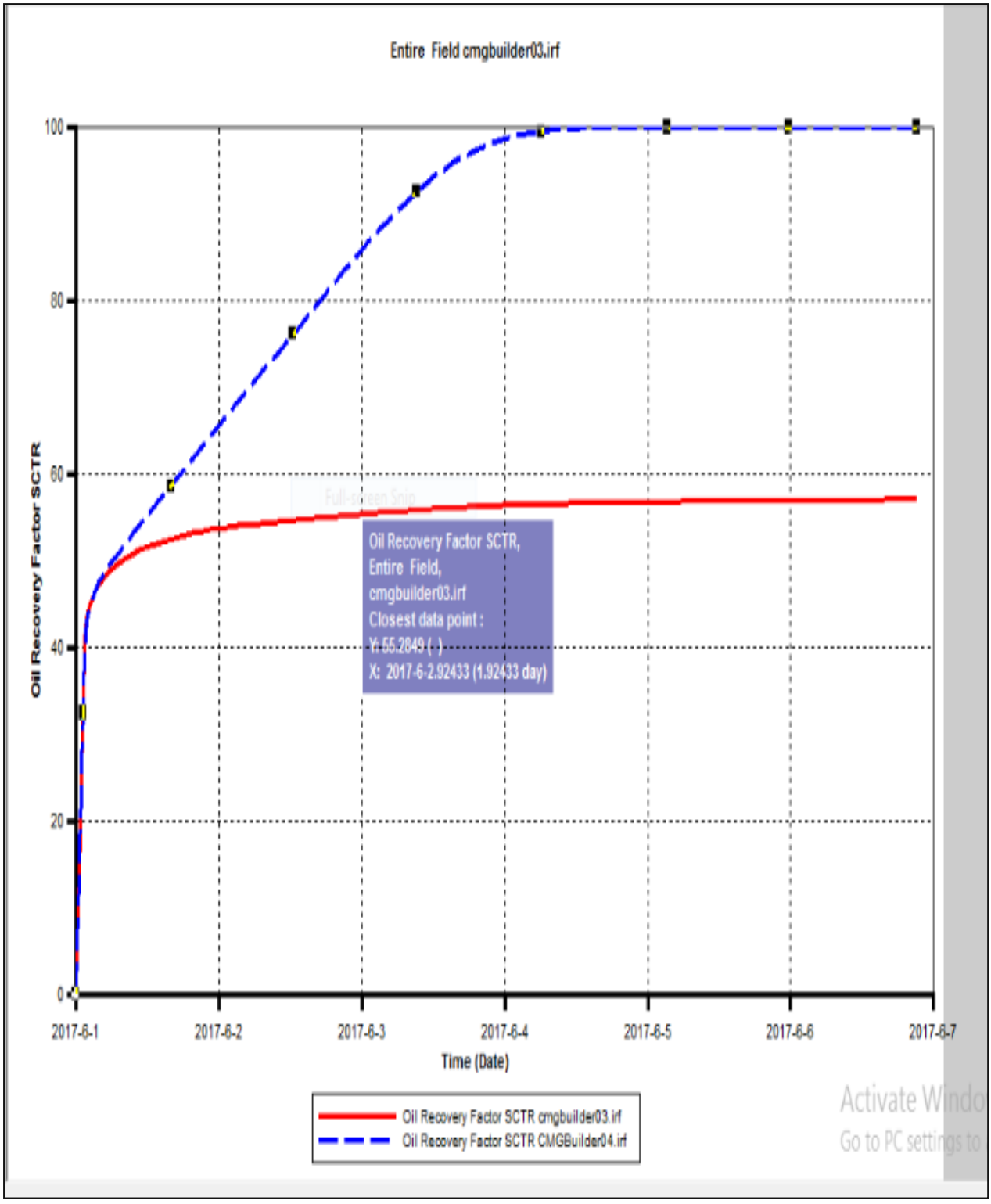


Figure 4-12: Comparison Between Oil Recovery Factor of Core-002 (Greenzyme Flooding And Water Flooding)

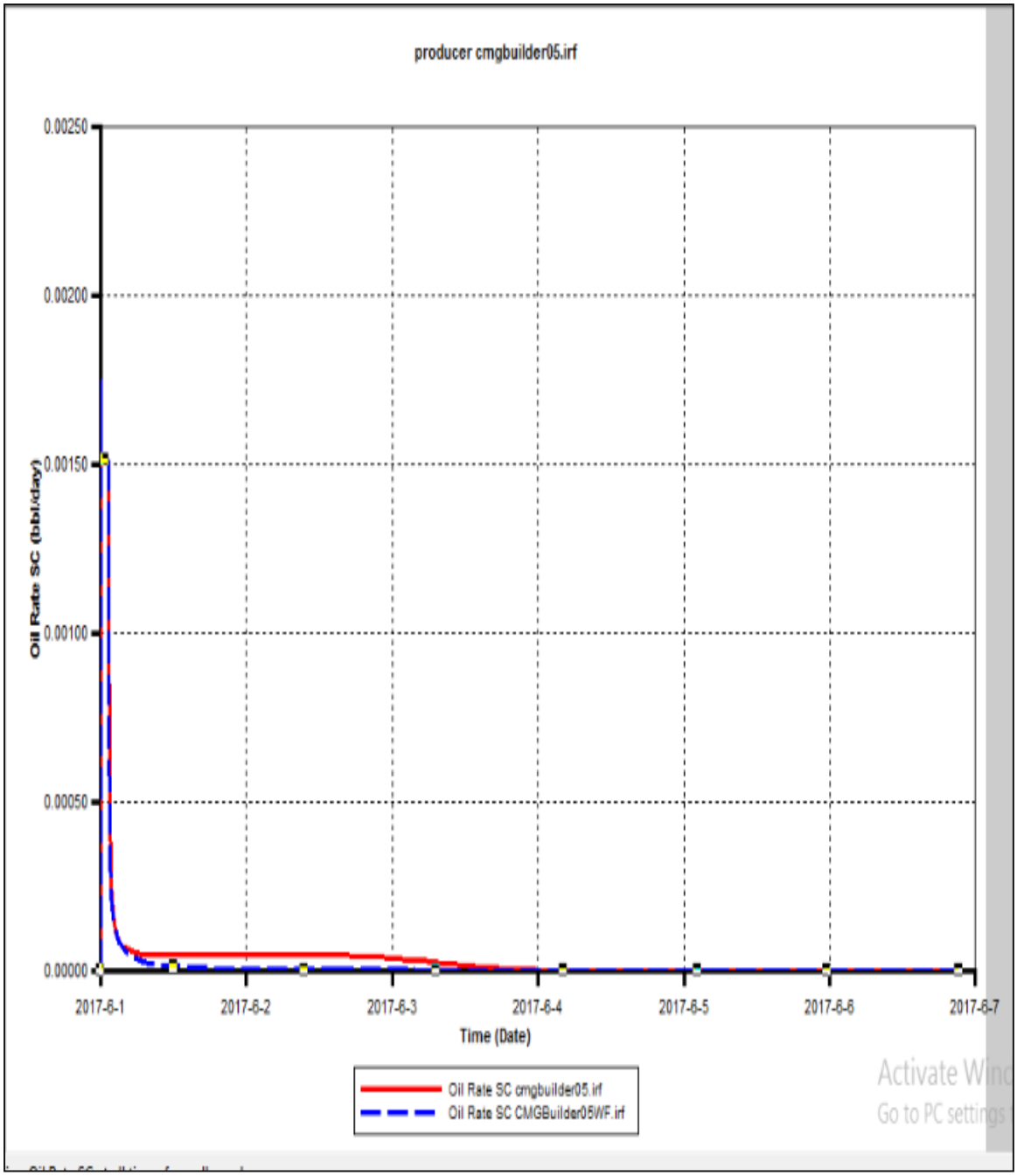


Figure 4-13: Comparison Between Oil Rate of Core-007 (Greenzyme Flooding And Water Flooding)

Using Greenzyme can increase the oil rate almost double from 0.00024908

bbl to 0.00029752 bbl (Figure 4-3) compared to water flooding which is about 19% additional oil.

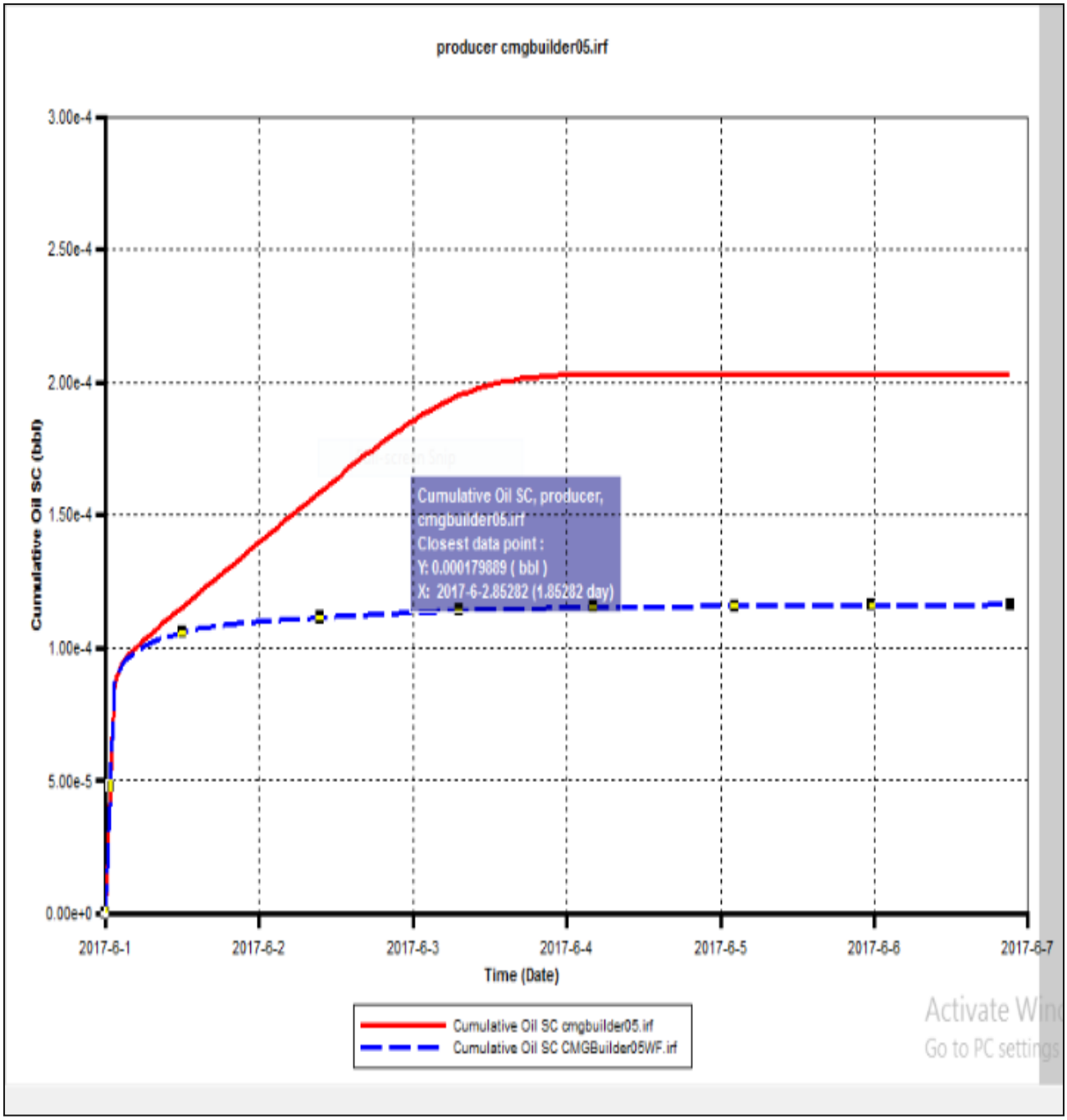


Figure 4-14: Comparison Between Cumulative Oil of Core-007 (Greenzyme Flooding And Water Flooding)

Using Greenzyme can increase the cumulative oil almost double from 0.00073281 bbl to 0.00127903 bbl (Figure 4-3) compared to water flooding which is about 74.5% additional oil.

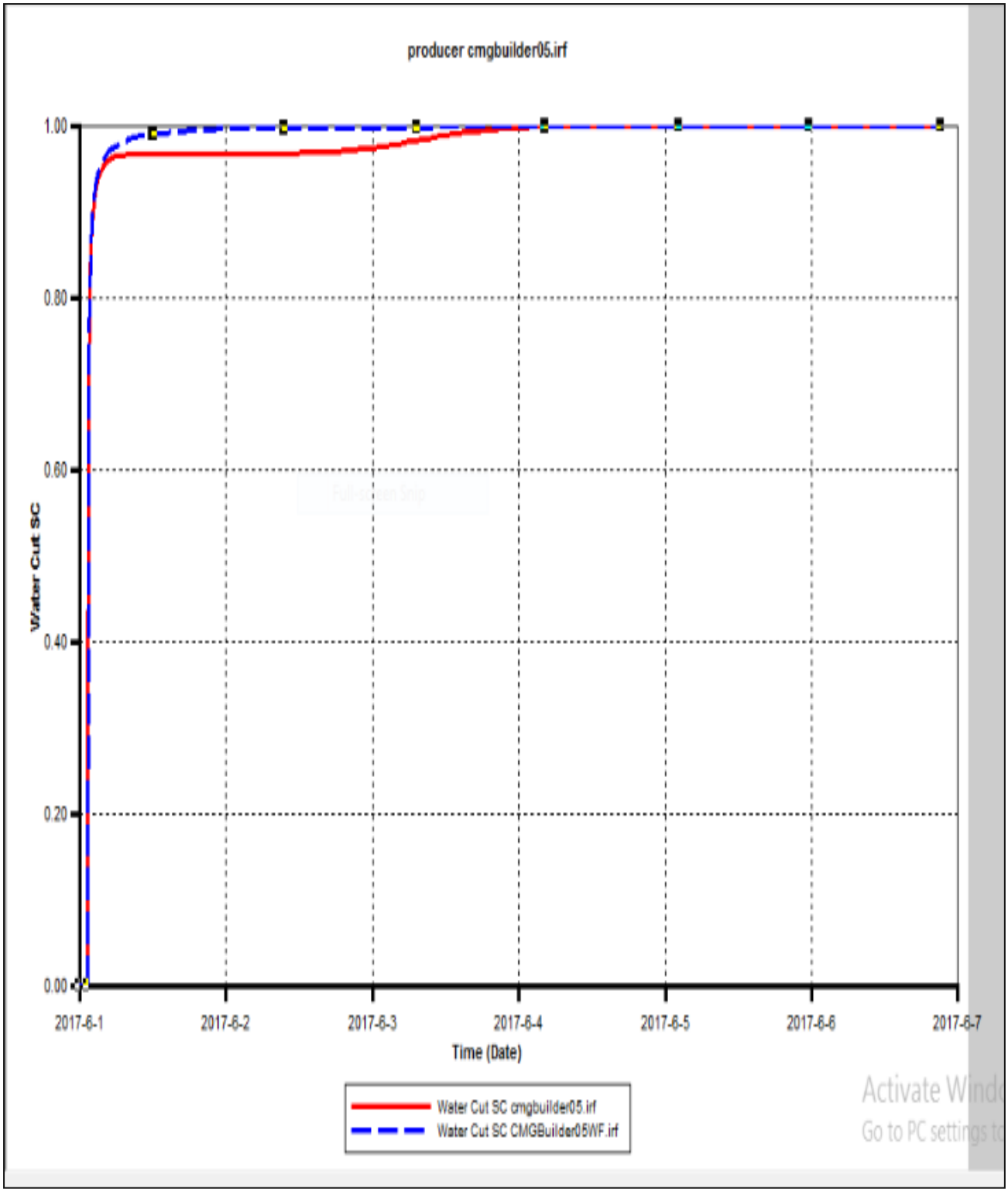


Figure 4-15: Comparison Between Water Cut of Core-007 (Greenzyme Flooding And Water Flooding)

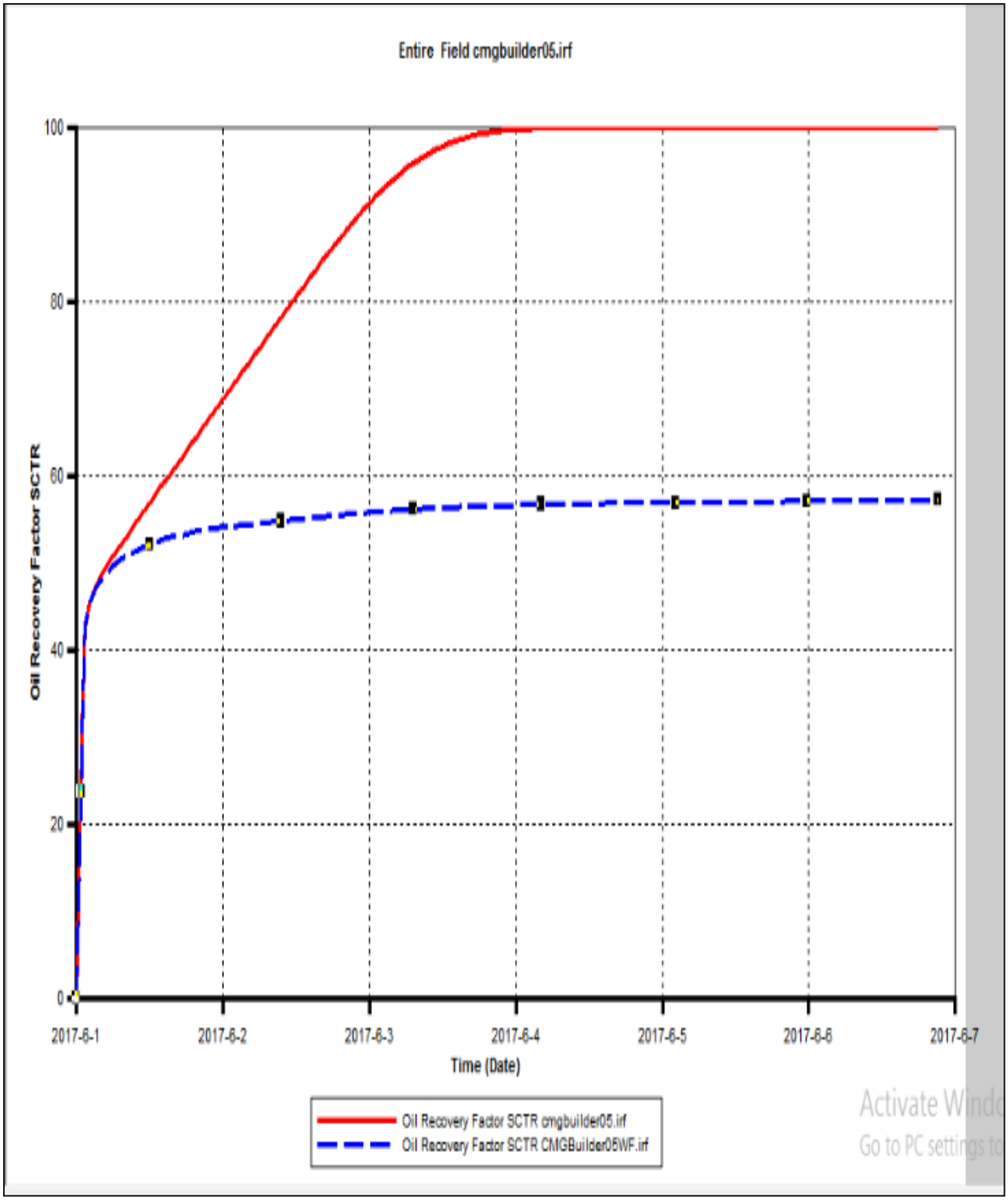


Figure 4-16: Comparison Between Oil Recovery Factor of Core-007 (Greenzyme Flooding And Water Flooding)

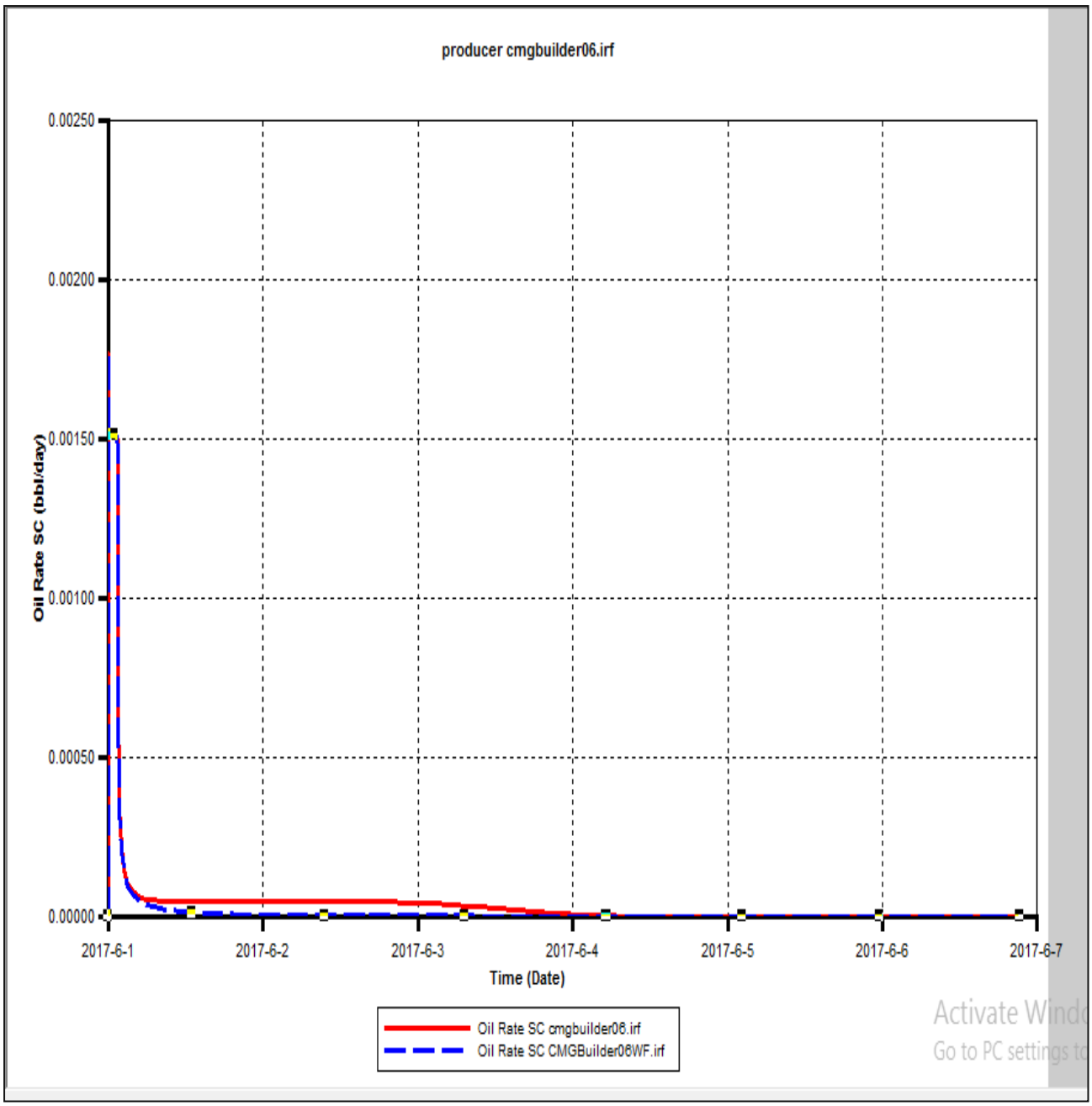


Figure 4-17: Comparison Between Oil Rate of Core-015 (Greenzyme Flooding And Water Flooding)

Using Greenzyme can increase the oil rate almost double from 0.00024971

bbl to 0.00027613bbl (Figure 4-3) compared to water flooding which is about 10.5% additional oil.

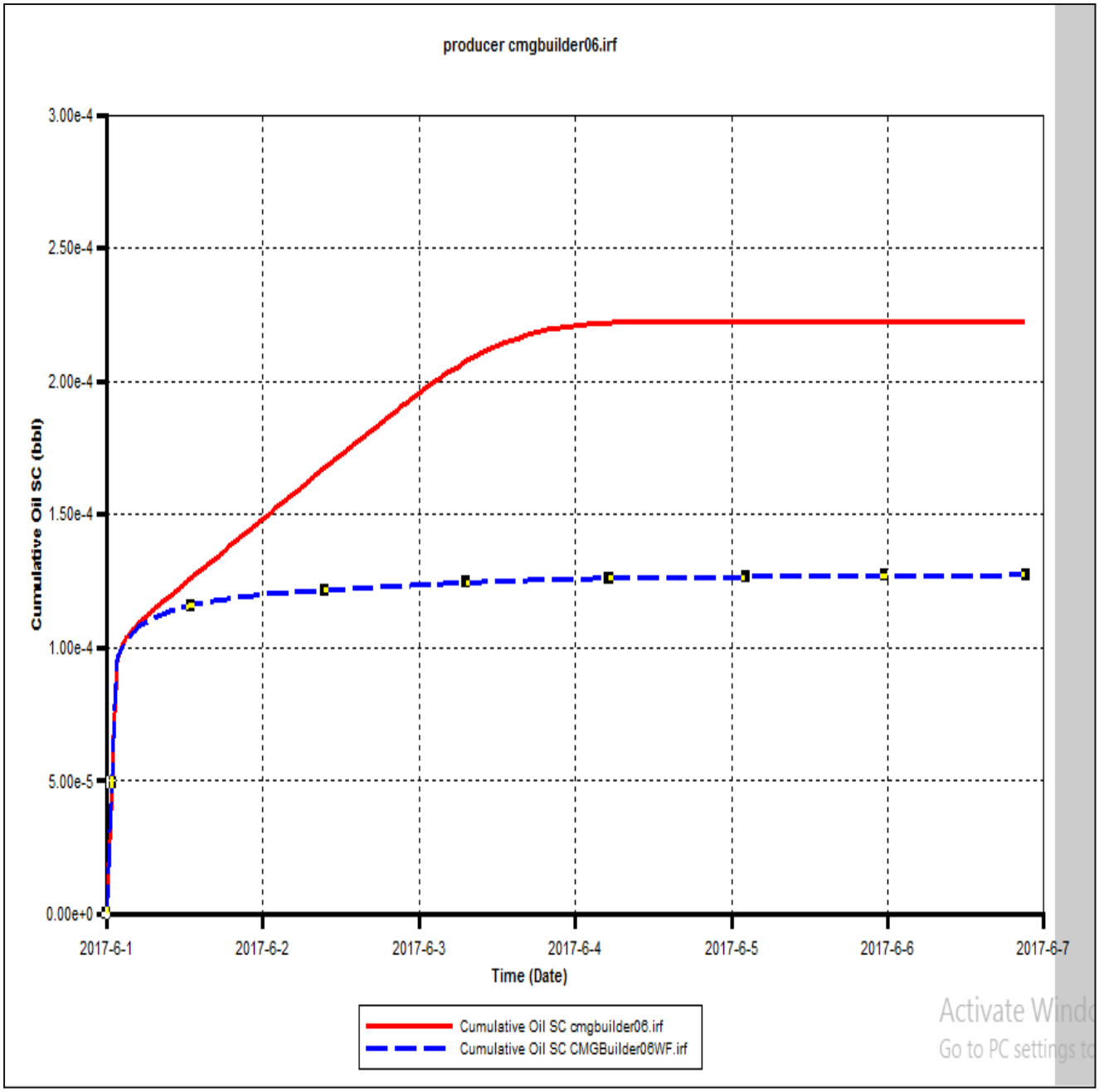


Figure 4-18: Comparison Between cumulative Oil of Core-015 (Greenzyme Flooding And Water Flooding)

Using Greenzyme can increase the cumulative oil almost double from 0.00080126 bbl to 0.00140131bbl (Figure 4-3) compared to water flooding which is about 74.8% additional oil.

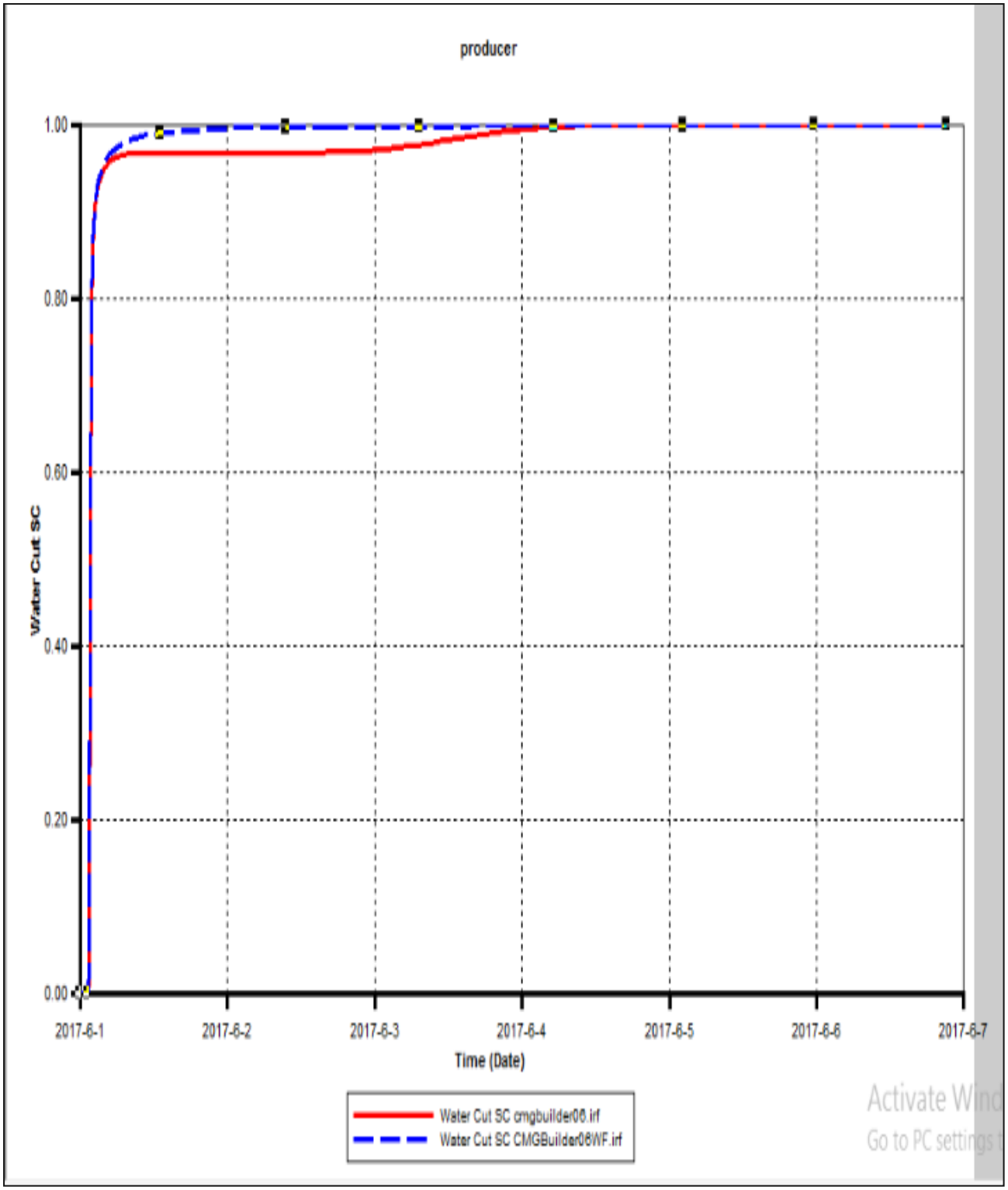


Figure 4-19: Comparison Between Water Cut of Core-015 (Greenzyme Flooding And Water Flooding)

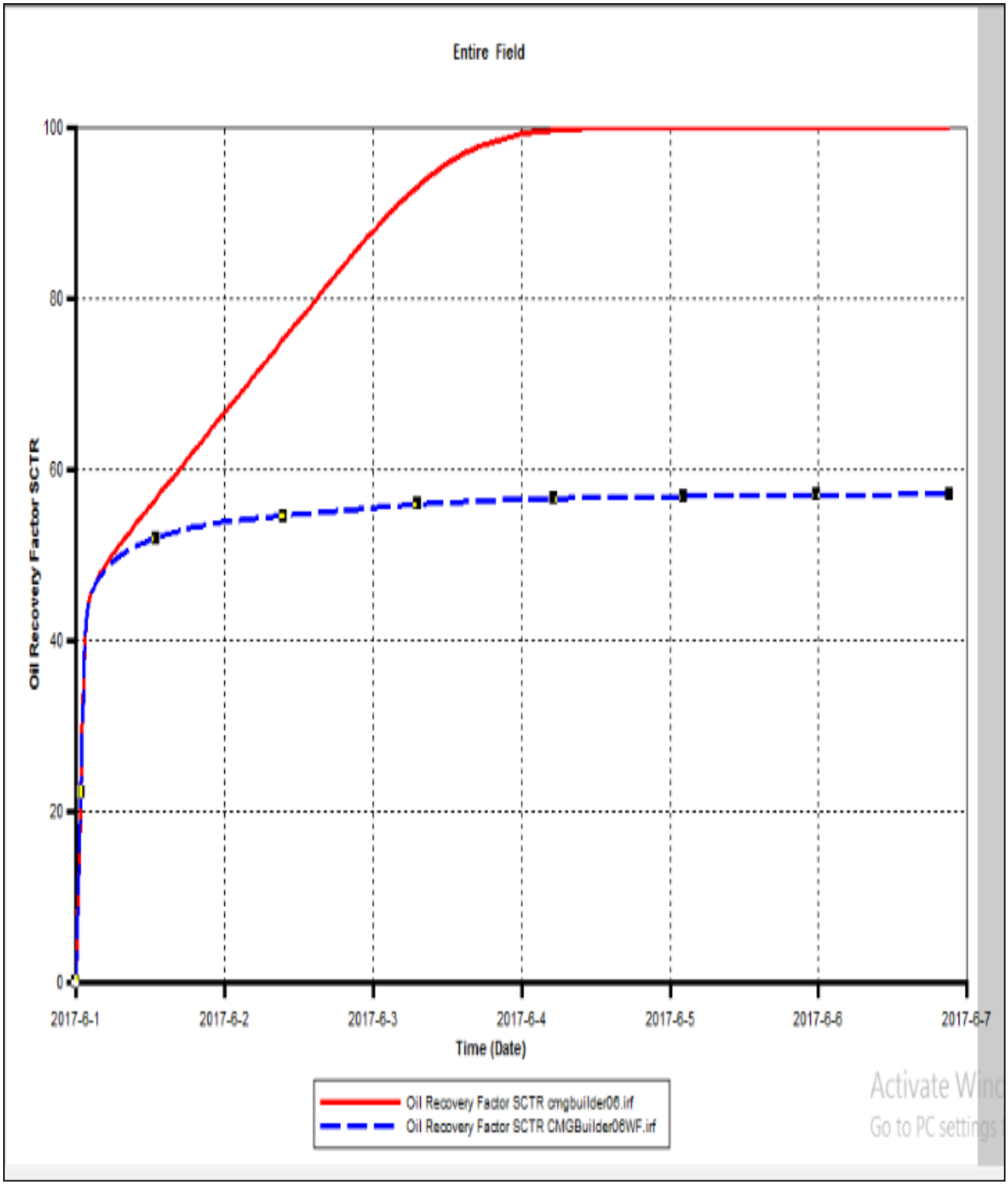


Figure 4-20: Comparison between Oil Recovery Factor of Core-015 (Greenzyme Flooding And Water Flooding)

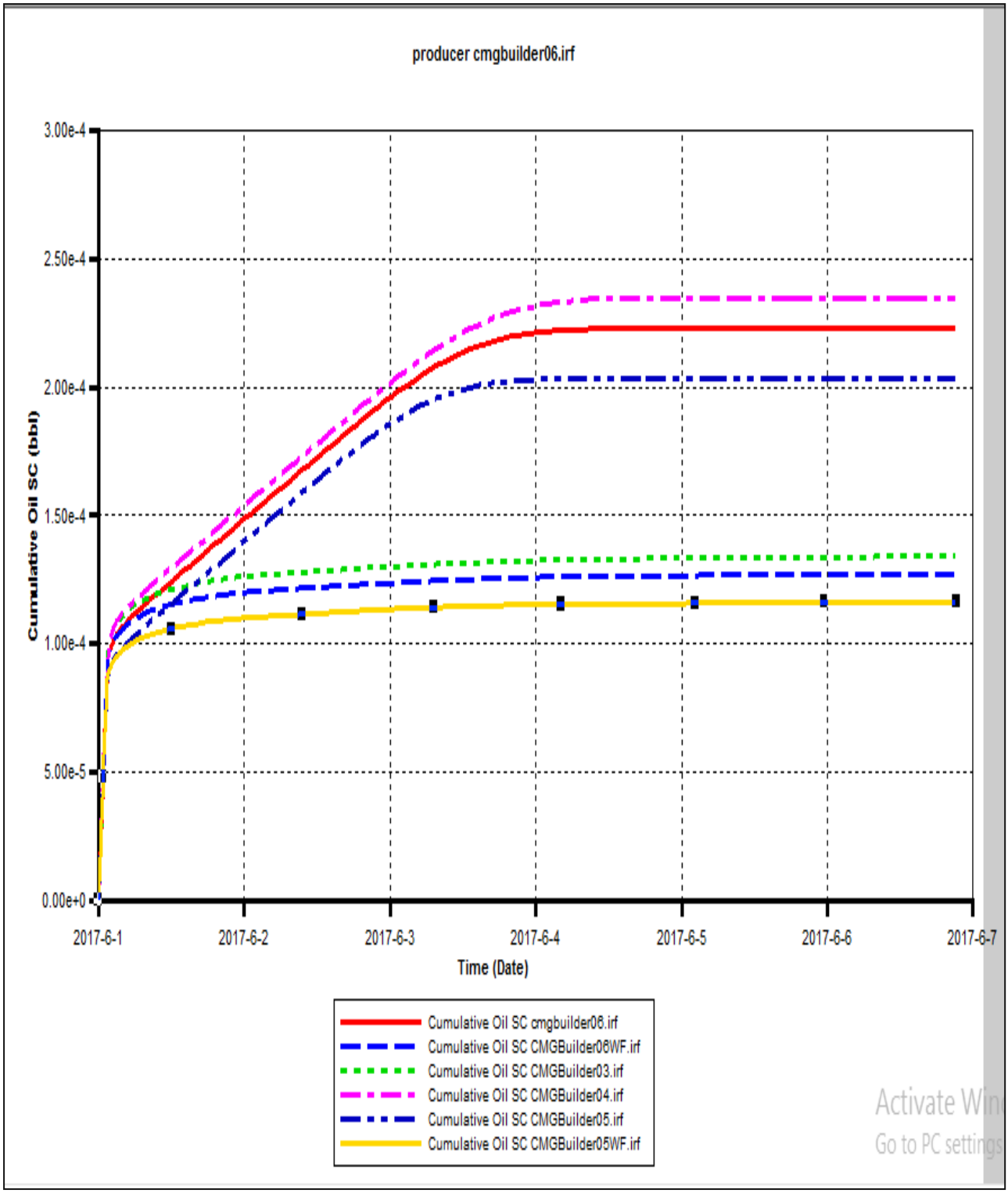


Figure 4-21: Comparison of Cumulative Oil For The Three Cores Using (Greenzyme And Water Flood).

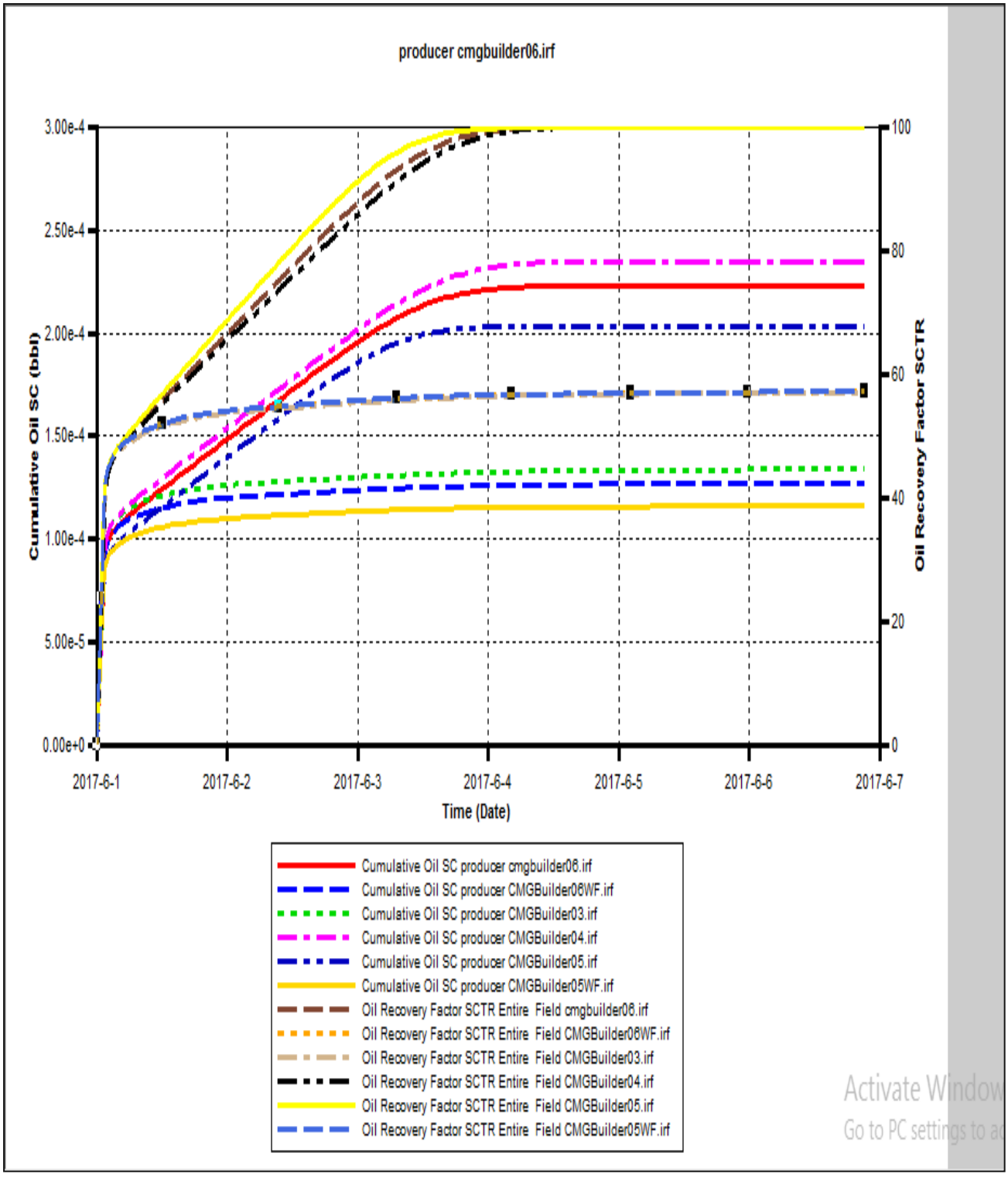


Figure 4-22: Comparison of Cumulative Oil And Oil Recovery Factor For The Three Cores Using (Greenzyme And Water Flood).

Summery Table for All results:-

Table (4-6) result summery

Core no.	Cum. Oil (bbl)		Oil Rate (bbl)		WC%		Incremental Oil%
	WF	GZ	WF	GZ	WF	GZ	
2	0.00084374	0.0014766	0.00025726	0.00026858	83	81.7	4.4
7	0.00073281	0.00127903	0.00024908	0.00029752	83.5	80.4	19
15	0.00080126	0.00140131	0.00024971	0.00027613	83.5	81.8	10.5

Chapter Five: Conclusions and recommendations

5.1 Conclusions:

- This analysis has been done to match laboratory core flood experiment – using core samples collected from Hamra East-8 – using CMG software.
- By determining the effect of Greenzyme it have been found that the greenzyme increase the recovery factor by 4.6,3.4, 2.7 for cores (15, 2, 7) respectively.
- The simulation model showed decrement in water cut by (81.7,80.4,81.8) respectively foe three cores.
- The simulation model also showed increment in cumulative oil by (4.4, 19, and 10.5) respectively for three cores.

5.2 Recommendations: -

- Detail Study for wells selection should be done before pilot implementation.
- It's highly recommended to conduct detail Study for Chemical Injection Parameters.
- The lab data should be up scaled to field scale before pilot implementation.
- It's highly recommended to make economic analysis before pilot implementation .

References:

1- Ahmed, T., (2010) Reservoir engineering handbook. 4 edition. Huston : Gulf Professional Publishing.

2- Don W. Green, G. Paul Willhite, 1998, Enhanced Oil Recovery , Henry L. Doherty Memorial Fund of AIME, Society of Petroleum Engineers.

3- HamidrezaNasiri, Kristine Spildo, and Arne Skauge (2009)Use of enzymes to improve waterflood PerformanceSCA2009-28, Center for Integrated Petroleum Research (CIPR), Bergen, Norway

4- He, L., Zhonghong., 2011.Biology enzyme EOR for low permeability reservoirs in Proceedings of theSPE114281 Presented at the SPE Enhanced Oil Recovery Conference, KualaLumpur, Malaysia, July19–21.

5- HushamELamin (2014) Design and Implementation of Enhanced Oil Recovery Cyclic Steam Stimulation (CSS) Program in Bamboo West Field-Sudan, Case Study. in SPE International Heavy Oil Conference and Exhibition, 8-10 December, Mangaf, Kuwait: SPE 172892.

6- Husham A. Ali ,Tagwa Ahmed Musa,(2015), Chemical Enhanced Oil Recovery Pilot Design for Heglig Main Field-Sudan, Abe Doroudi, Computer Modeling Group (CMG).SPE-177984-MS

7- James G ,2015, Handbook Of offshore Oil And Gas Operations, Gulf Professional Publishing Is An Imprint Of Elsevier 225 Wyman Street ,Waltham,Ma 02451, USA

8- James J .Sheng , 2013,Enhanced oil recovery field case studies,Bob L. Herd Department of Petroleum Engineering, Texas Tech University, P.O. Box 43111, Lubbock, TX 79409, USA3

9- john gray, Analysis of Enhanced Oil Recovery Using Enzymes Prue Ranch Oilfield Texas, may 30,2007, jumpstart energy services, LLC (Houston, TX).

10- Larry W. Lake. Publisher, Prentice Hall,1989,Enhance Oil Recovery, Original Form, The University Of California .Digitized ,Jul ,2011

11- Li JiaHua, Li Li Xiang, 3 Analysis Report of Crude Oil Recovery Enhancement with enzyme, China March 2002.

12- Ott, W.K., Nyo, T., Aung, W.N., Khaing, A.T., 2011 EEORsuccessinMann Field, Myanmar. In: SPE114231Presented at the SPE Enhanced Oil Recovery Conference, KualaLumpur, Malaysia, July19–21.

13- Q.X., Ma, X.P., Zhou, L.H., Shao, D.B., Wang, X.L., Qin, B.Y., 2007.EOR pilot tests with modified enzyme in China. In: Proceeding of the SPE107128 Presented at SPE Europe/EAGE Annual Conference and Exhibition, London, United Kingdom, June 11–14.

14- SahilVaswani , Mohd Ismail Iqbal and Pushra Sharma, (2015), Study of the various EOR methods (chemical injection and steam flooding with case study), Dehradun, (India)

15- Satter,A.,Iqbal,G.M,Buchwalter,J.L, 2008.Paartiaal Enhance Reservoir Enginnering : Assisted With Simulation Software . Pennwell

16- Tarang Jain , Akash Sharma,2012, New Frontiers In EOR Methodologies By Application Of Enzymes, SPE EOR Conference at Oil and Gas West Asia, 16-18 April, Muscat, Oman

17- Teknica 2001, Enhance Oil Recovery , Calgary , Alberta.

18- Vladimir Alvarado & Eduardo Manrique, 2010 Elsevier Inc., Gulf Professional Publishing, Enhanced Oil Recovery, field planning and development strategies,

19- William K, Thu Nyo, Win NyuntAung, AungThetKhaing,EEOR Success in Mann Field, Myanmar,2011, Kuala Lumpur, Malaysia.

20- Y. Y. Foo and R. D. Tewari, PETRONAS; K. C. Kok and A. Elrufai,(2016),Laboratory Evaluation of Chemical EOR Process for Viscous and High EACN Oil in East African OilfieldIPTC-18601-MS,

21- Y. Wang and A. Kantzas, SPE, University of Calgary; B. Li and Z. Li, China University of Petroleum (East China);and Q. Wang and M. Zhao, Dongxin Oil Company,(2008)SINOPEC, P.R.China.