MAJOR PROJECT REPORT
ON

SICK WELL ANALYSIS

UNDER THE MENTORSHIP OF

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SUBMITTED BY

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DECLARATION BY AUTHORS

This is to declare that this report has been written by us. No part of the report is plagiarized from other sources. All information included from other sources has been duly acknowledged. We declare that if any part of the report is found to be plagiarized, we shall take full responsibility for the same.

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CERTIFICATE

This is to certify that this project report titled **"Sick Well Analysis"** submitted to **University of Petroleum and Energy Studies, Dehradun** is a bonafide record of work done by **Mr. Aamir Lokhandwala** and **Ms. Vidhi Malik** under my supervision from **September 2014** to **April 2015**.

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- **Aamir Lokhandwala & Vidhi Malik**

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EXECUTIVE SUMMARY

The main motivation in undertaking this topic was to work on an area which provides value to the industry: this project entails this sentiment in a day-to-day basis. It is pertinent to understand what a "sick" well means, as its definition is highly contextual. If a well deviates from its anticipated behaviour due to any reason, the probable causes for such anomalies need to be investigated in order to restore the well to its "healthy" state of functioning.

A basic reservoir engineering background suggests that problems may occur in a well in or more of the following heads. Reservoir dynamics may lead to inefficient flow from the reservoir to the wellbore. Wellbore dynamics may cause issues related to the vertical lift performance. Moreover, problems at the surface facilities end may prevent the efficient and holistic recovery of hydrocarbons from the reservoir.

Literature survey was done in the initial phase of the project work. During literature survey, it was found that although a set of guiding recommendations exist for treating sickness in a well, the actual solution is generally extremely specific for each condition. Preventive and control measures taken in the case studies were analysed and recommendations have been provided by us in an attempt to treat the sick wells.

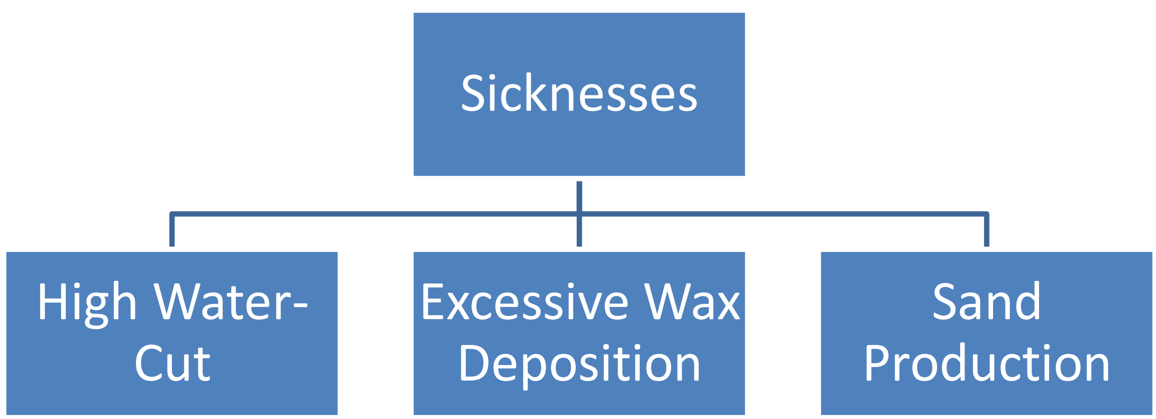
In this project, the aim was to analyze given candidates to estimate their health, identify the problems which cause them to deviate from their anticipated behaviour, and provide recommendations in order to restore their health. If a well was found to be sick, appropriate identification of the causative problems and the remedial solutions or workover recommendations were suggested. This project work addresses the sicknesses of high water-cut through coning and channeling prevention, excessive wax deposition via chemical injection treatment, and sand production using properly designed gravel pack.

1. Introduction

In this project work, the aim is to analyze given candidates to estimate their health, identify the problems which cause them to deviate from their anticipated behaviour, and provide recommendations in order to restore their health. If a well is found to be sick, appropriate identification of the causative problems and the remedial solutions or workover recommendations are to be suggested.

In this project work, the following are the areas of 'sicknesses' that are worked upon. Relevant data has been taken from industry sources for the same.

- High water-cut
- Excessive wax deposition
- Sand production



As for the problem of increased water-cut, the methodology is using diagnostic plots derivative technique which was explained by Chan, K. S, showed that the log-log plot of production data, WOR and the WOR derivative respect to time provide more insight and information of well performance evaluation on identification of the mechanism that causes the excess water production.

The problem of wax deposition due was evaluated by studying the production history of the well. The mechanical scraping of the well lead to the increase in production, and in our conclusion we propose the chemical injection method for our wax inhibition program in the particular well.

High sand production is generally accompanied by increased water production. This can be resolved by appropriate sand control techniques, after the appropriate mesh-sieve analysis has been performed to ascertain the grain size distribution.

1.1. Literature Review

Increased water-cut leads to increased costs and subsequently lower profitability of an oilfield venture. The sources of produced water include formation water, aquifer, and injected water. The formation water may originate from a water saturated zone within the reservoir or zones above or below the pay zone. Many reservoirs are adjacent to an active aquifer and are subject to bottom or edge water drive. Water is often injected into oil reservoirs for pressure maintenance or secondary recovery purposes; this injected water is one of sources of water production problem. Technical efforts for water control were mainly on the development and implementation of gels to create flow barriers for suppressing water production. Based on systematic numerical simulation studies on reservoir water coning and channeling, it was discovered that log-log plots of WOR vs time and GOR vs time show characteristic trends for different mechanisms. The time derivatives of WOR and GOR were found to be capable of differentiating whether the well is experiencing water and gas coning, high-permeability layer breakthrough, or near-wellbore channeling.

Paraffin wax deposition costs the oil industry billions of dollars worldwide for prevention and remediation. Paraffin precipitation and deposition in crude oil transport flow lines and pipelines is an increasing challenge for the development of deepwater subsea hydrocarbon reservoirs. If sufficiently deposited over time, wax can partially or totally block oil production to uneconomical levels requiring shutdowns and/or various remediation treatments. The increasing exploitation of deepwater fields makes it critical to understand the mechanism of wax depositions and how to prevent and remediate wax deposits in deepwater production operations.

Sand production (or sanding) is the production of the formation sand alongside with the formation fluids (gas, oil and water) due to the unconsolidated nature of the formation. Produced sand has essentially no economic value. On the contrary, formation sand do not only plug wells to reduce recovery rates, it also erode equipment and settle in surface vessels. Controlling formation sand is costly and usually involves either slowing the production rate or using gravel packing or sand-consolidation techniques. As a result of this, sand production is a major issue during oil and gas production from unconsolidated reservoirs. Sand production is initiated when the formation stress exceed the strength of the formation. The formation strength is derived mainly from the natural material that cements the sand grains, but the sand grains are also held together by cohesive forces resulting from immovable formation water (residual water). The stress on the formation sand grains is caused by many factors notably; tectonic actions, overburden pressures, pore-pressures, stress changes from drilling, and drag forces on producing fluids. Sand production is one of the oldest problems of oil field. It is usually associated with shallow formations as compaction tends to increase with depth. But in some areas, sand production may be encountered to a depth of 12,000ft or more. Sand production higher than 0.1% (volumetric) can usually be considered as excessive, but depending on the circumstances, the practical limit could be much lower or higher.

Certain reports and industry manuals were also made use of to enhance the interpretation and analysis of the problems associated with the wells taken into consideration for this major project.

2. High Water-cut

2.1. Overview

Worldwide, it is estimated that an average of three barrels of water are produced for each barrel of oil The total cost of separation, treatment and disposal of water has been estimated to be about $50 billion/year in the oil industry. This is because water is commonly co-produced with the hydrocarbons saturating the reservoir rock. Excessive water production is prevalent in mature fields globally where the ratio of water to oil produced increases to nine. This can have an impact on the profitability of oil and gas assets in mature fields.

Therefore, it is important to fully understand the different mechanisms that contribute to undesired water production to better evaluate existing information, identify additional tests, and design the optimum solution to the problem. A large number of chemical and mechanical conformance/water control technologies are available to mitigate water-related issues. These technologies not only shutoff or slow down water production, they also significantly increase hydrocarbon production rates and extend the life of the reservoir.

In general, two basic classifications of the problems exist in the form of near-wellbore problems and reservoir-related problems.

Near-Wellbore Problems	Reservoir-Related Problems
Casing leaks	Coning or cresting
Temporary chemical isolation	Fractures, fissures or voids
Lost circulation while drilling	Channel from injector
Lost circulation while workover	High permeability streak
Channelling behind casing	Completion near a water zone
Water shutoff for gravel pack	Fracturing job went to water
Plug-back	Watered-out zone
Shutting-off perforations	Acidizing near water zone

Table 1: Categorization of problems related to water production

Once the water production mechanism is understood, an effective strategy can be formulated to control water production. Therefore it is very important for engineers to identify exactly the problem which causes high water cut production.

Reservoir Porous Media Problem

The sources of produced water include formation water, aquifer, and injected water. The formation water may originate from a water saturated zone within the reservoir or zones above or below the pay zone. Many reservoirs are adjacent to an active aquifer and are subject to bottom or edge water drive. Water is often injected into oil reservoirs for pressure maintenance or secondary recovery purposes; this injected water is one of sources of water production problem.

The water flooded reservoir development problem

A major problem occurs when the reservoirs enter the super high water cut stage; therefore, it is more complicated and difficult stage of reservoir development. The difficulties can be explained considering the following issues

i) The injection-production system is not in a perfect relationship,
ii) A high ratio of the numbers of production/ injection wells which needs to be adjusted in a suitable value,
iii) Low degrees of monitoring and control of water flooding,
iv) An unbalanced reservoirs internal pressure, is a high pressure difference between different layers and reservoir blocks,
v) A low water flooding efficiency, and
vi) A large number of wells with casing damage.

High permeability streak problem

In water-drive reservoirs and reservoir that are subjected to water flooding, reservoir heterogeneity can result in water channeling through high permeability streaks; oil, gas, and water flow mainly along the path of least resistance, which are usually the higher permeability parts of the reservoir.

Unfavorable mobility ratio problem

The unfavorable mobility ratio could potentially be considered a major factor in increasing the excess water production due to low viscosity of the aquifer water compared to high viscosity of heavy and medium heavy oil this leads to premature water breakthrough due to a fingering phenomenon.

Fissures or Fractures

Natural fracture zones or when wells are hydraulic fractured, the fracture often unintentionally breaks into water zones .In such cases, coning through hydraulic fracture can result in substantial increase in water production In addition, stimulation treatments can cause barriers breakdown near the wellbore often, impermeable barriers (e.g., shale or anhydrite) separate hydrocarbon-bearing strata from water saturated zone that could be the source of the excess water production In unfractured reservoirs often stratification and associated permeability variations among various layers can result in channeling between an injector and a producer or from an edge water aquifer to the producers.

Water Coning Problem

Water coning is caused by vertical pressure gradient near the well. The well is produced so rapidly that viscous forces overcome gravity forces and draw the water from a lower connected zone toward the wellbore. Eventually, the water can break through into the perforated or open-hole section, replacing all or part of the hydrocarbon production. Once a breakthrough occurs, the problem tends to get worse, as higher cuts of the water are produced.

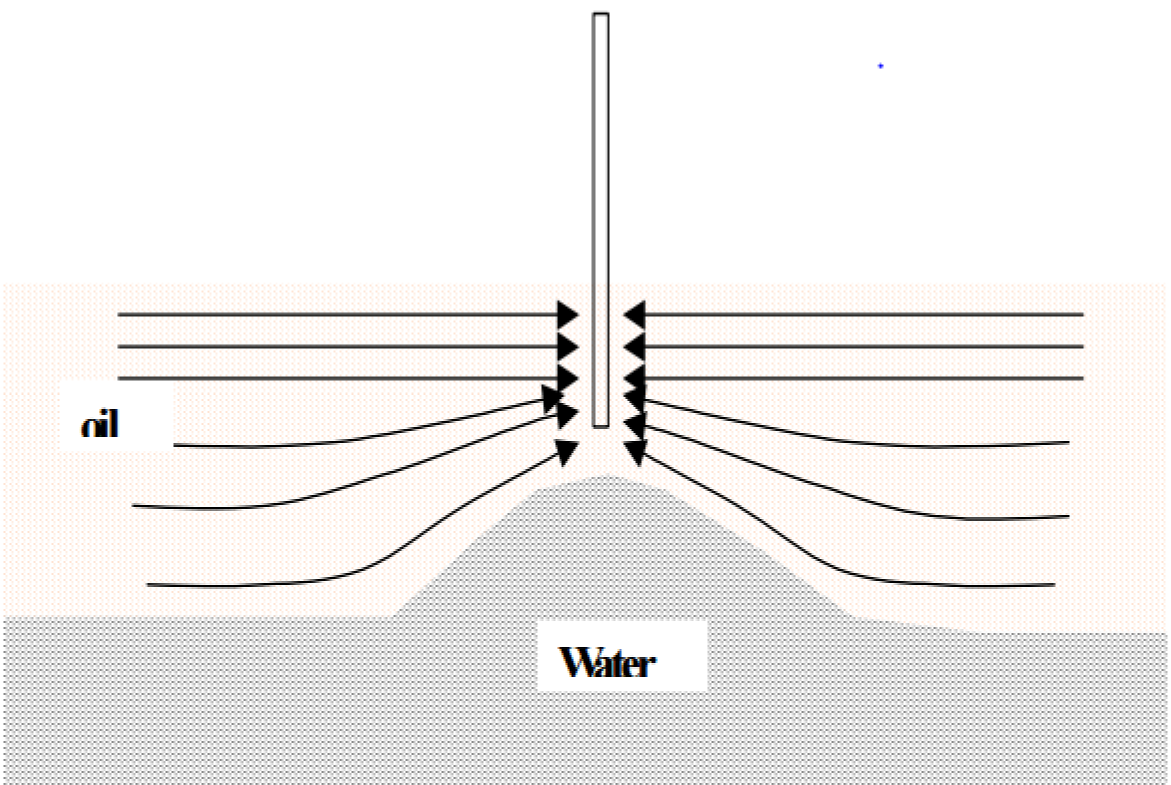


Figure 1: Schematic representation of water coning in vertical wells

Vugs and Faults

Deviated and horizontal wells are prone to intersect faults or fractures. If these faults or fractures connect to an aquifer, water production can jeopardize the well.

Well Problems

As previously mentioned excess water production is one of the major technical, environmental and economic problems associated with oil and gas wells production, it is always a challenging task for field operators the cost of handling and disposing produced water can significantly the economic producing life of the well, and can cause severe problems including tubular corrosion, fines migration, and hydrostatic pressure created by high fluid levels in the well. The latter is detrimental to oil production.

Well integrity Problem

Well integrity is application of technical, operational and organizational solutions to reduce risk of uncontrolled release of formation fluids throughout the life cycle of a well .There are various facets to well integrity, including accountability/responsibility, well operating processes, well service processes, tubing/annulus integrity, and tree/wellhead integrity and testing of safety systems.

Casing/tubing leak, packer leak Problem

The common completion related problems are channel behind casing, completion into or close to water zone, completion into the zones where water saturation is higher than the irreducible water saturation allows the water to be produced immediately Casing leak results in unwanted entry of water and unexpected rise in water production, often casing leaks occur where there is no cement behind the casing.

Cement channel Problem

Channels behind casing can result from poor cement-casing or cement-formation bonds. Channels behind casing can develop throughout the life of a well, but are most likely to occur immediately after the well is completed or stimulated.

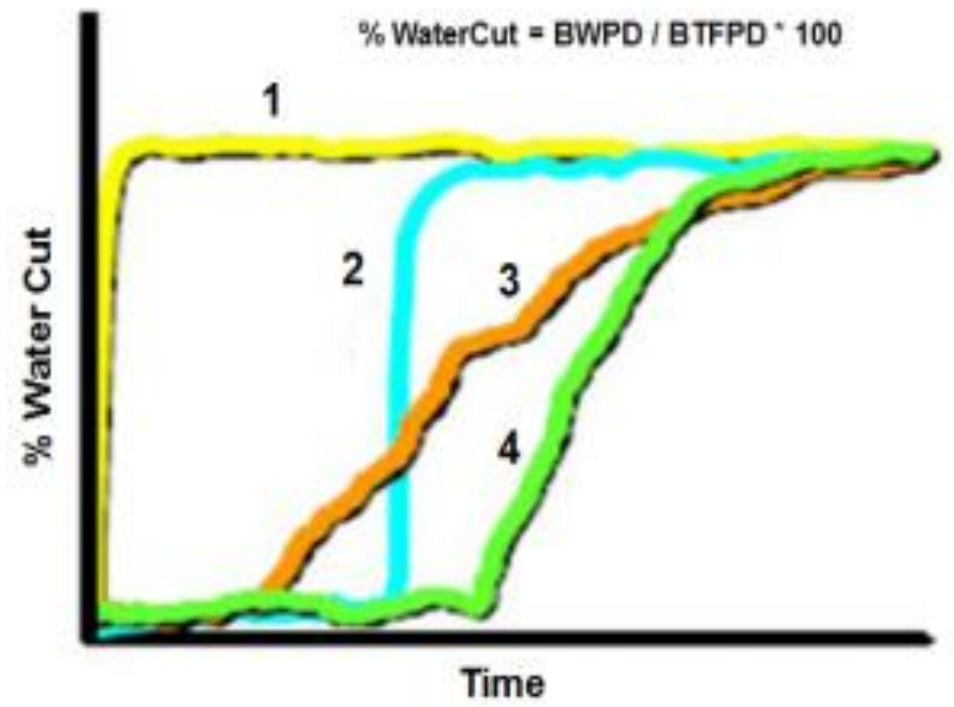
2.2 Methodology

Various tools and technologies are available in oil industry for controlling undesirable water production, each of these technologies has been developed for certain types of water production problems, whereas appropriate selection of the water control technology depends on the correct identification and diagnosis of the water production problem source. Hence, water production problems often are not properly diagnosed. In fact, incorrect, inadequate, or lack of diagnosis has been cited as one of the major reasons that water control treatments have been ineffective. Proper diagnostic techniques significantly enhance success of traditional treatments, both technically and commercially.

In this project work, a discussion of such techniques is presented.

Production Trends

Production trends provide a good indication of the type of water-related problem. For example, a steep increase in the water cut may indicate that a casing leak or channeling behind casing has occurred. On the other hand, a slow water cut upturn may suggest that water has slowly encroached from a water zone below. Diagnostic plots (water-oil-ratio (WOR), WOR-derivative vs. time) can be also used to aid in this regard.



Casing Leaks (1)(2)
Flow behind casing (1)
Conning or cresting (3)(4)
Channel from injector (4)
High permeability streak (4)
Completion near a water zone (1)(2)
Fracturing job went to water (1)(2)
Watered-out zone (3)(4)

Figure 2: Conformance problems associated with water cut trends

If the reservoir is under waterflooding, higher WOR in certain wells compared to others in the same area can be a good indicator of water channeling from injector to producer wells. In other cases, when robust geological and simulation models of a large reservoir are available, water production problems can be analyzed and diagnosed by the oilfield operator.

Well Logs

Well logs are often referenced to identify water production problems. Table 1 shows logs mainly used to identify water issues. Open-hole logs are the most widely available source of information for initial water-oil-contact (WOC), fluid saturation, and permeability of the reservoir.

Problems	Open-Hole Logs	Cement Evaluation Logs	Casing Evaluation Logs	Pulsed Neutron Logs	Production Logs
Lost	X				

circulation while drilling					
Lost circulation while workover	X				
Coning or cresting	X				X
Casing leaks			X	X	X
High perm streak	X				X
Completion near water zone	X			X	X
Fracturing job to water		X		X	X
Channeling behind casing	X	X		X	X
Channel from injector				X	X
Watered-out zone	X				X

Table 2: Main Applications of Logging Tools to Diagnose Conformance Problems

A cement bond log (CBL) is the primary tool to evaluate the quality of cement and diagnose the location of cement failure to pinpoint where the repair is needed. After a well is put on production, production logging is one of the most commonly used tool that can reveal information on the type of fluid and flow rate using spinner, temperature, and pressure data. This information can indicate the source of water production as well as potential zones for further analysis development.

Conventional Plots

Conventionally, water cut vs time linear plots were used to show the progress and severity of the excessive water production problems, as can be seen from Figure 2. Although these plots can also show a drastic change in the water cut indicative of the sudden failure of well completion or rapid breakthrough of a high water conductivity channel, the information provided by water cut plots is limited. Regardless of multilayer channeling or coning, the shapes of water-cut plots are similar. Nevertheless, it is an inadequate technique to confirm or identify what type of source caused the excess of water production.

Diagnostic Plots

There is not a unique way to diagnose all excess-water problems. Log-log plots of the WOR (rather than water-cut) vs time were found to be more effective in identifying the production trends and problem mechanisms.

In this project work, the technique of utilizing **Chan Plots** to determine excessive water and gas production mechanisms as seen in petroleum production wells, has been developed and verified by Chan, K. S , which can be considered as the most appropriate methodology for identifying the source of the water production problems. The application of this technique is a proof that log-log plots of WOR (Water/Oil Ratio) vs. time or GOR (Gas/Oil Ratio) vs. time show different characteristics response trends for different excess water production mechanisms, and moreover confirmation that WOR and GOR derivatives respect to time are founded to be capable of differentiating the response of the well whether the well is experiencing water and gas coning. In water channeling, the slope of WOR and WOR derivatives are positive constants, while water conning, shows a changing negative slope. Therefore the diagnostic plot till now is considered as a unique technique as an easy, fast, and inexpensive method to identify excessive water and gas production mechanisms.

Diagnostic plots derivative technique which was explained by Chan, K. S, showed that the log-log plot of production data, WOR and the WOR derivative respect to time provide more insight and information of well performance evaluation and identification of the mechanism that causes the excess water production. It can be applied either for the entire well life or any chosen period, such as the water flooded period.

Using the time derivative of WOR, coning and channeling can be discerned. Furthermore, the change in slope of the parameters prove to be good indicators to differentiate normal displacement and production behaviour, multilayer water breakthrough behaviour, rapid layer depletion and water recycling behaviour.

This technique has several advantages:

1. It mainly uses available production history data.
2. It can be used to rapidly screen a great number of wells.
3. It entails the best reservoir engineering principles and practices.
4. It could yield results to form the basis for conducting a production mechanism survey, compare mechanisms between adjacent wells, good production wells vs problematic production wells, and by area or by well pattern.

2.3 Analysis & Interpretation

In this project work, for the set of candidate wells A(1) to A(10) referred in the Appendix 7 at the end of this work, the following set of water diagnostic plots using derivative methods has been formulated.

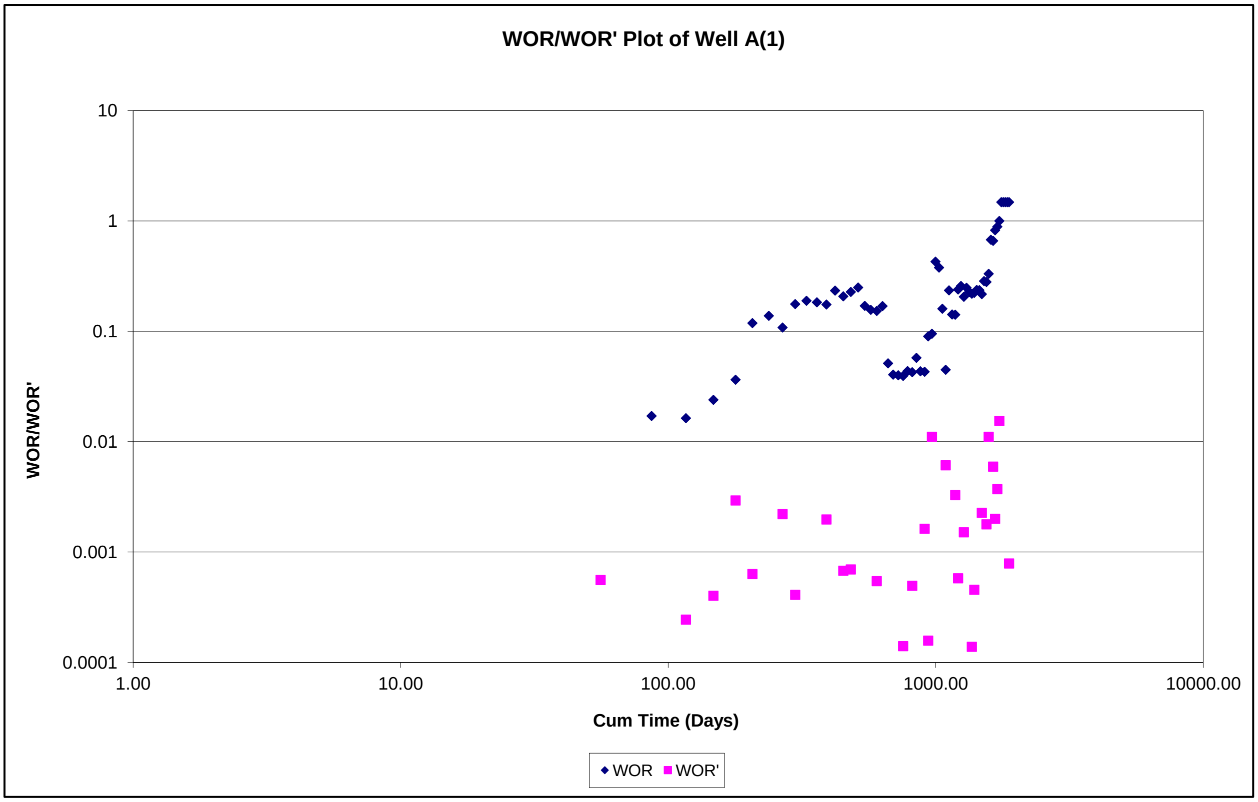


Figure 3: Interpretation - Late time channeling followed by coning

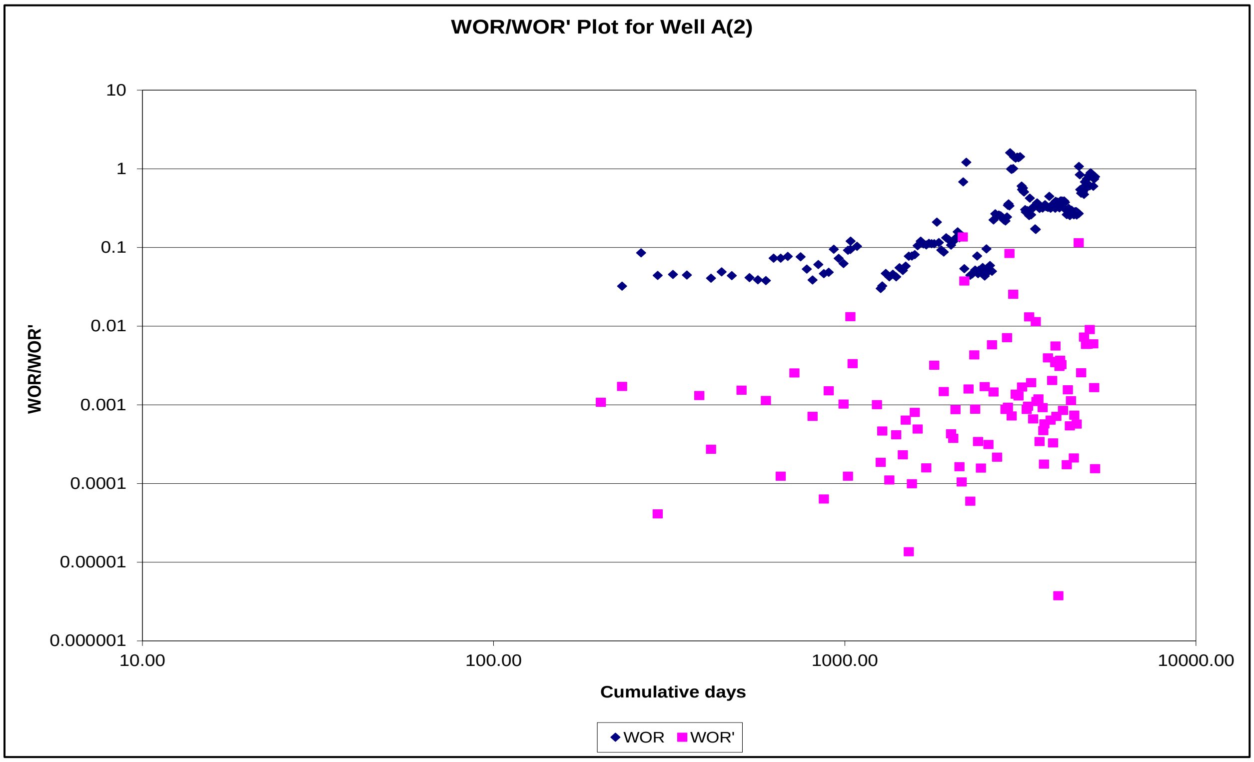


Figure 4: Interpretation - Normal production behaviour

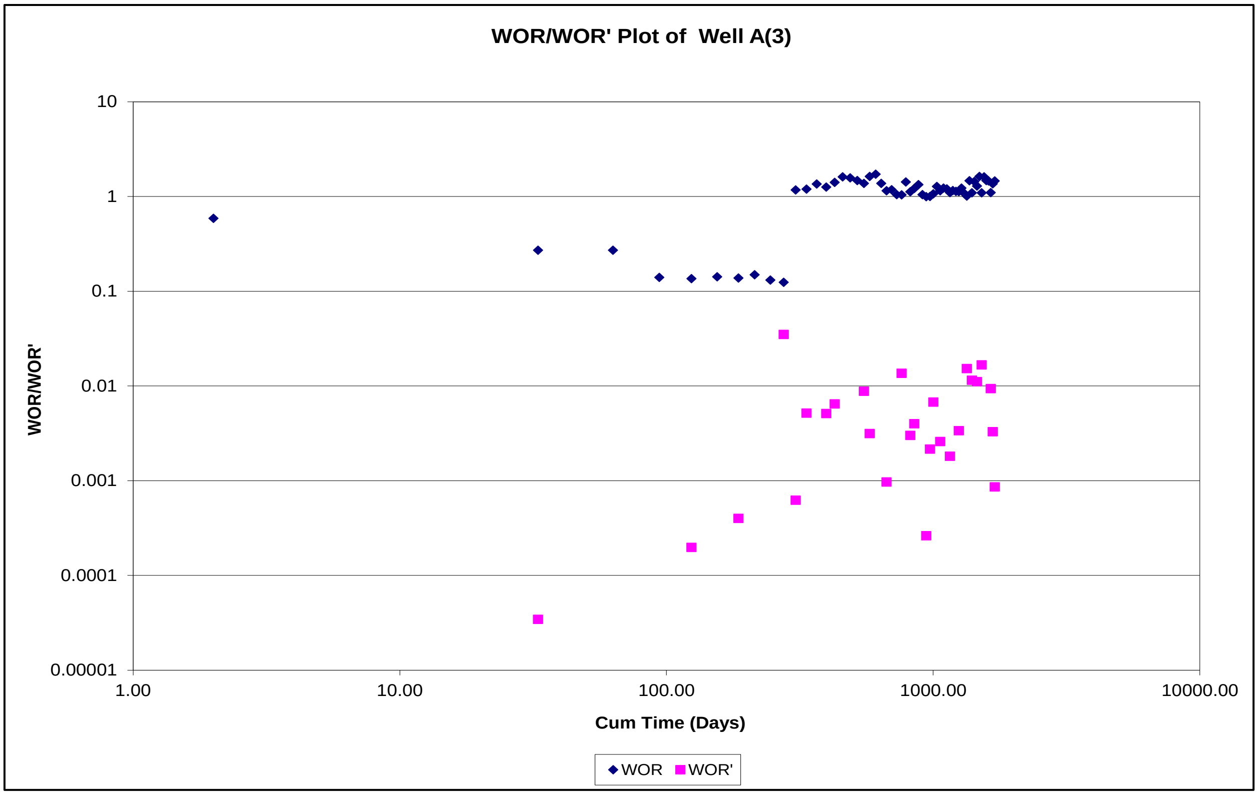


Figure 5: Interpretation – Coning (water cone has stabilized)

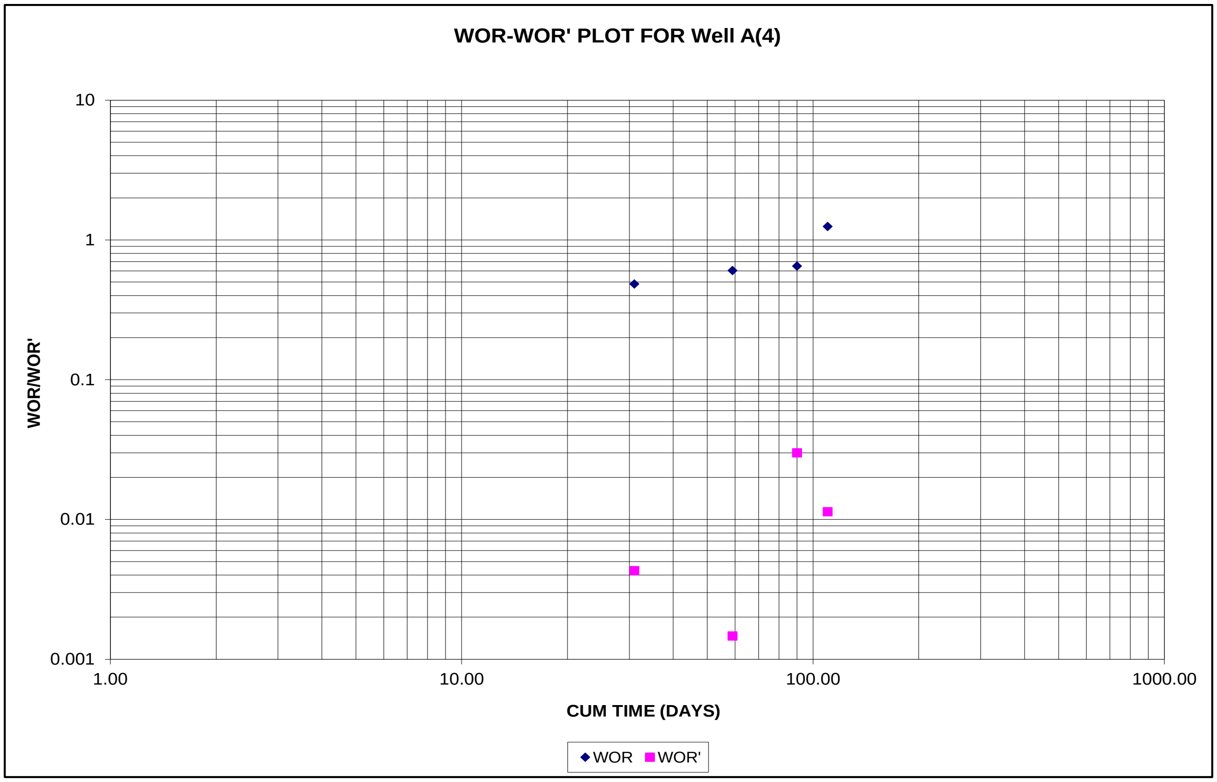


Figure 6: Interpretation – Limited production data/initial stages of production

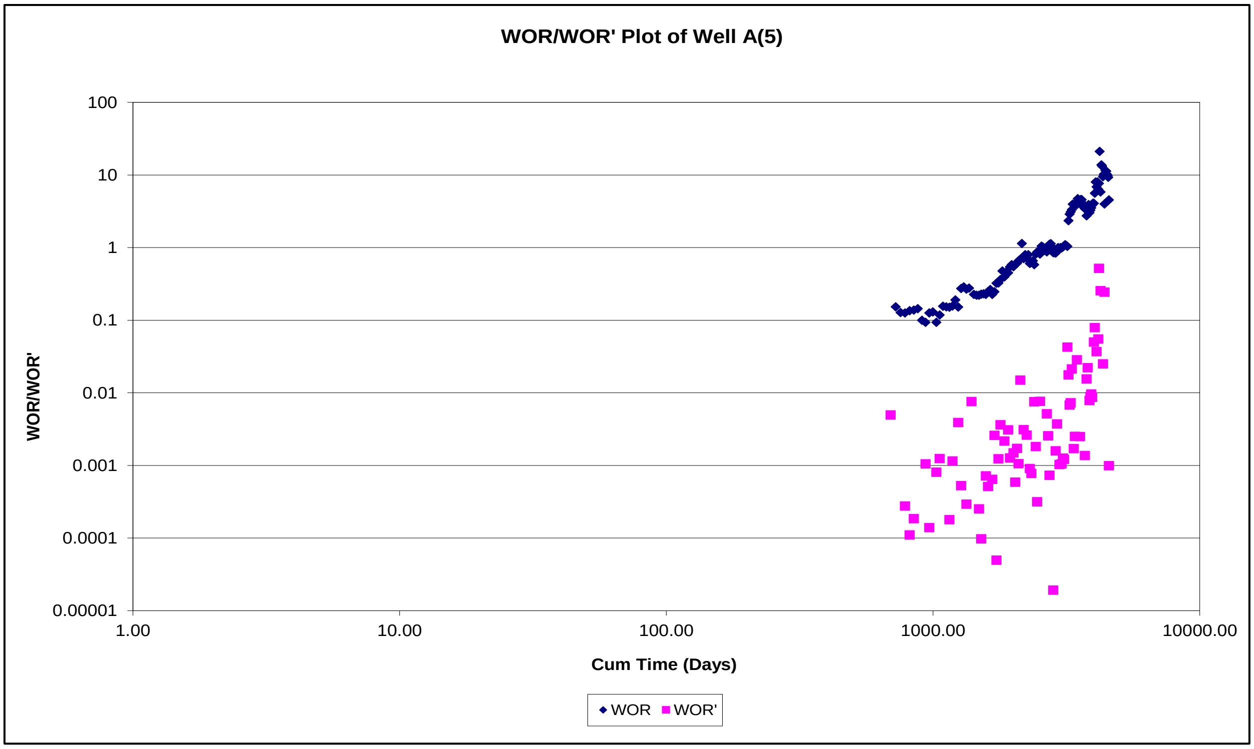


Figure 7: Interpretation - Channeling

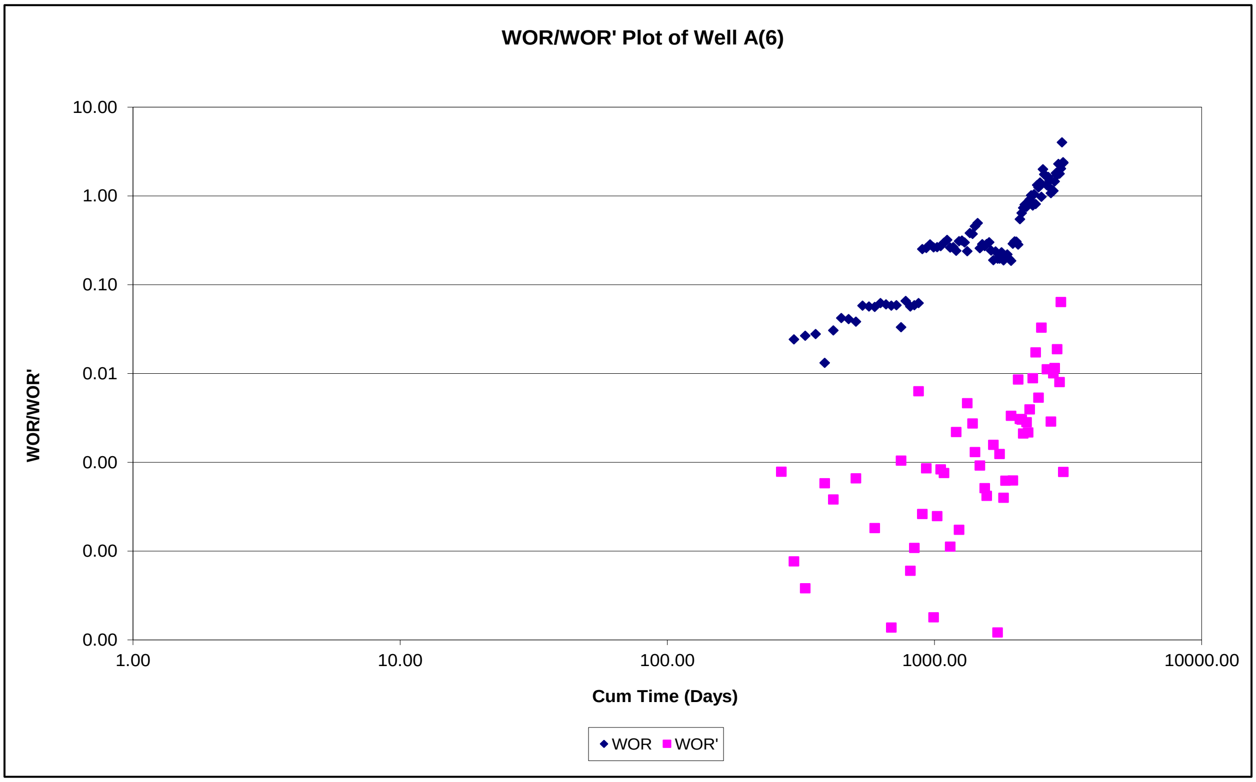


Figure 8: Interpretation - Channeling

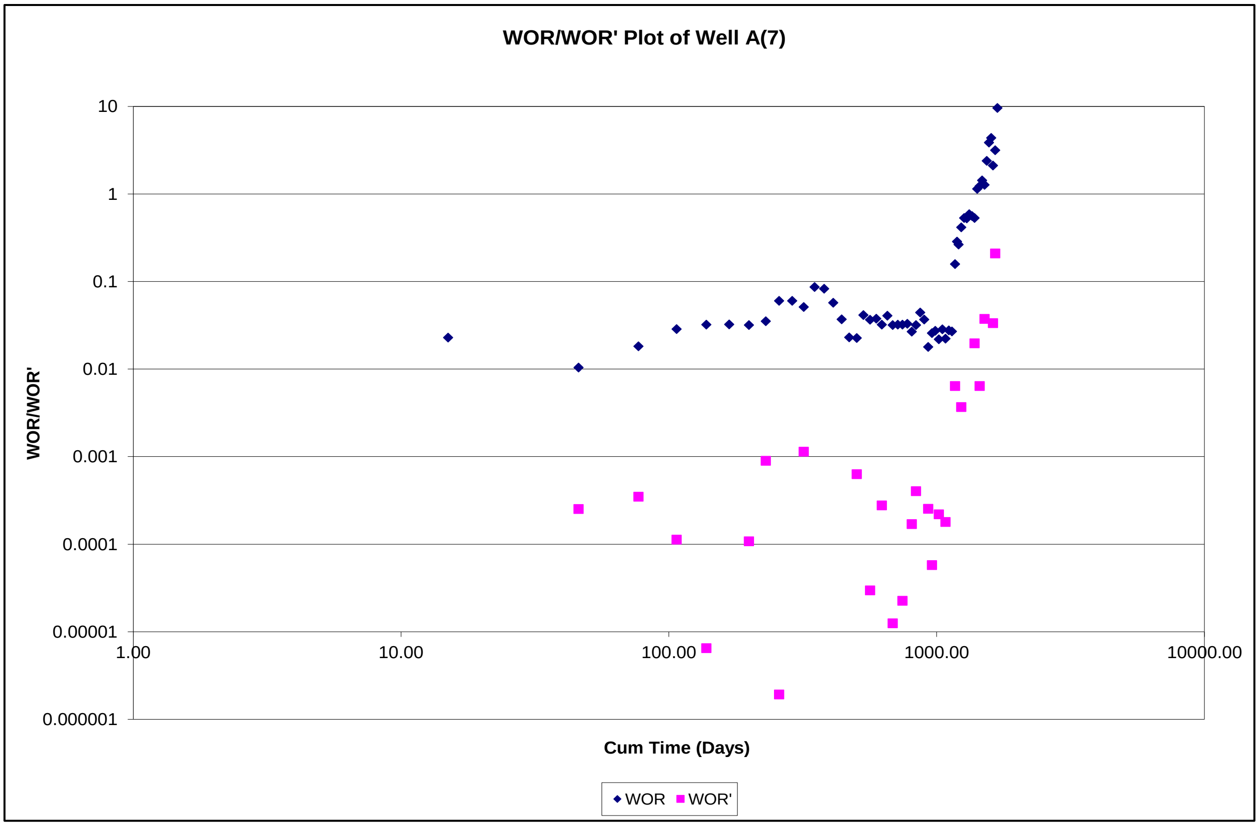


Figure 9: Interpretation - Channeling

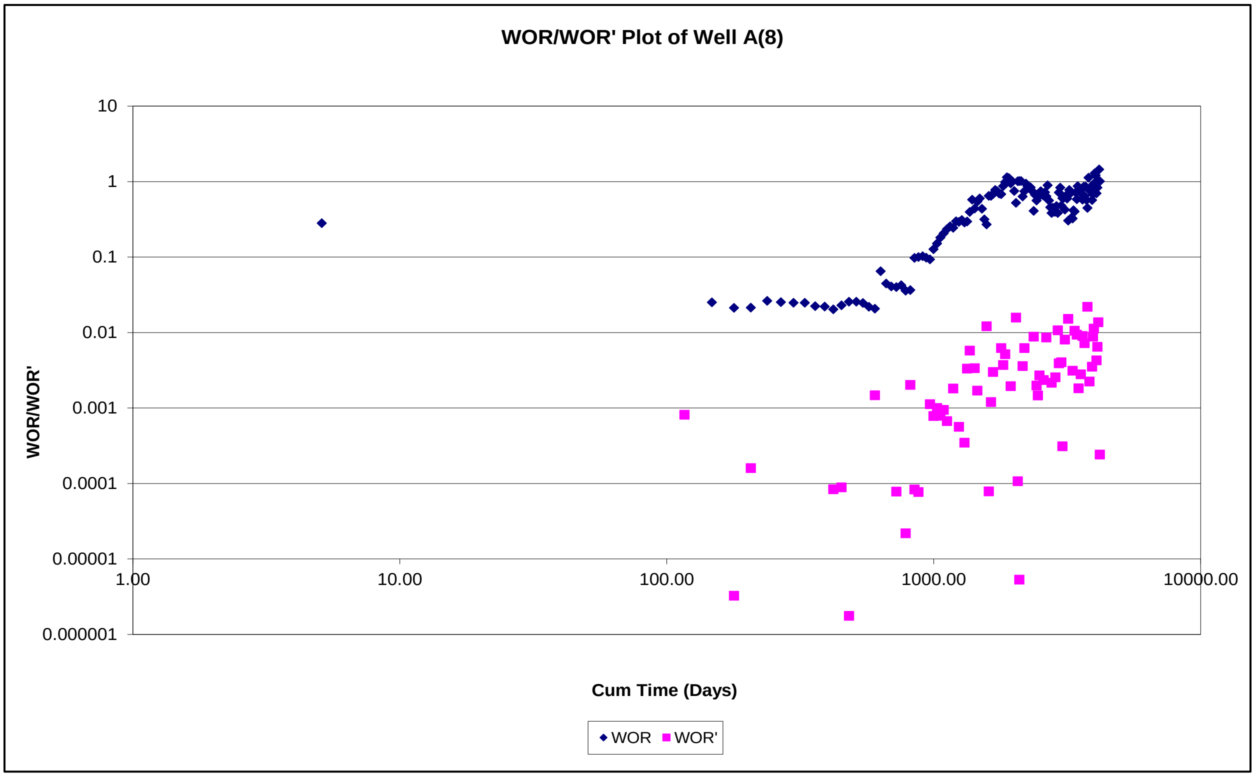


Figure 10: Interpretation – Late time channeling

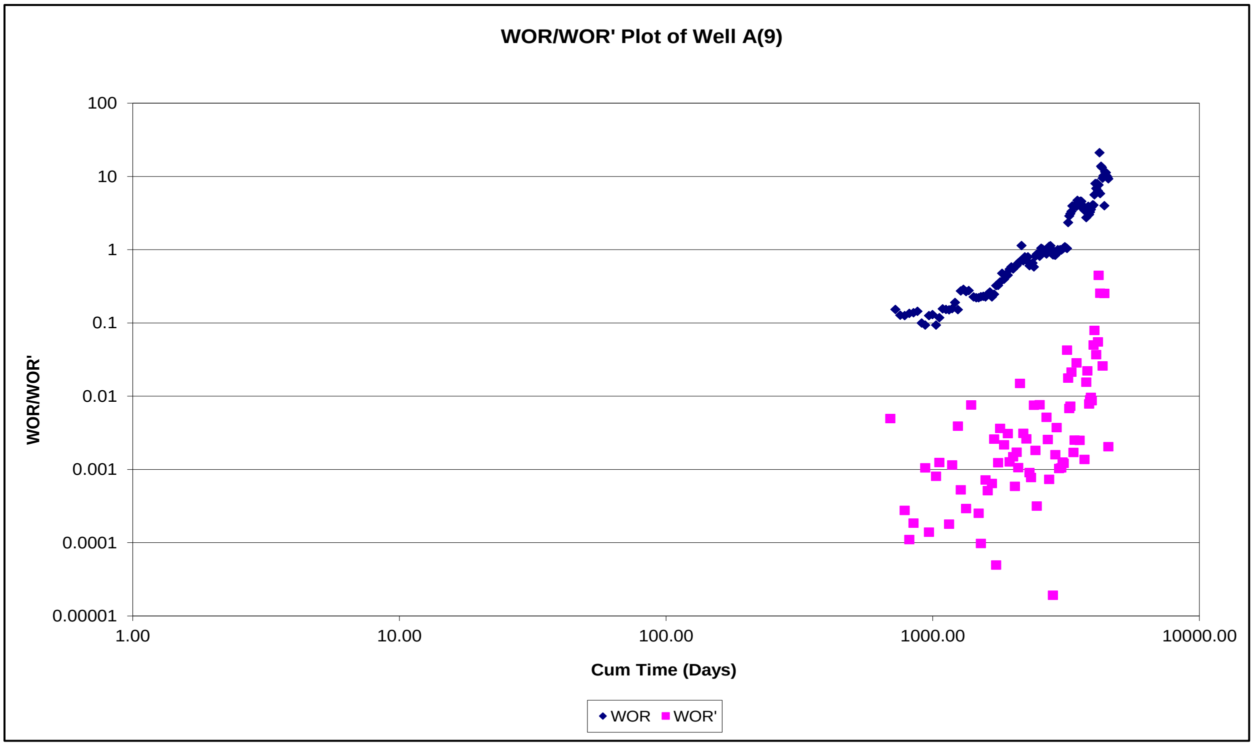


Figure 11: Interpretation - Channeling

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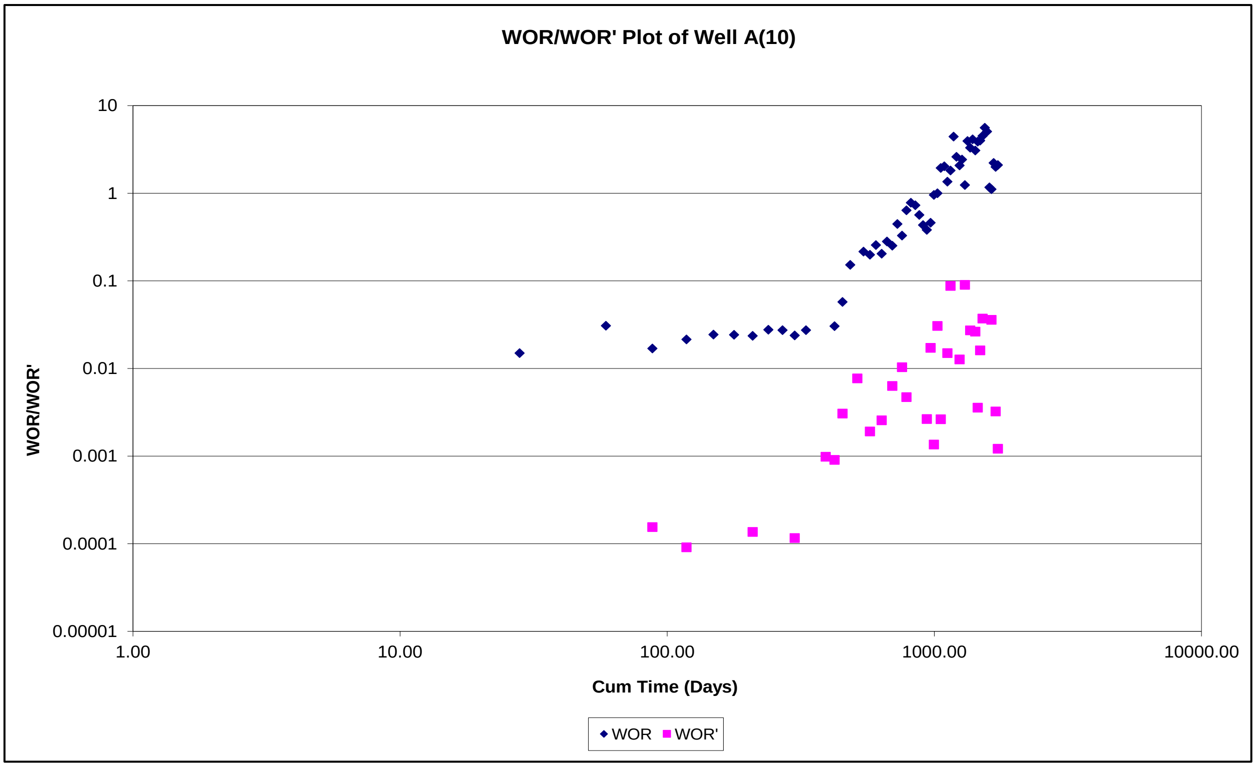


Figure 12: Interpretation – Coning

2.4 Conclusion & Recommendations

A good practice is to plot (log-log) the entire production history to get a big picture, and then discern the periods in which the production mechanisms change. For the same, any period of interest may be selected and plots of WOR or GOR with their time derivatives can yield information on the excessive water production mechanism in that period. This should be done for wells not only with known production problems, but also for good wells in the same area producing from the same formation. Some suggested procedures include the following:

- Look for normal production behaviour
- Determine the normal WOR or GOR or WGR slopes
- Check the trend of their derivatives
- Use expanded plots for the period of interest

Several practical solutions have been developed to try to minimize the level of severity of water coning and channeling. The approach, basically, is to delay the time to water breakthrough such as increasing the distance between the bottom perforation and the original oil water contact or minimize the amount of water in the wellbore thus reducing the hydrostatic head. Some of the methods are briefly described below.

Perforation Squeeze-off and Re-completion

In cases where the reservoir deposition is such that shale barriers are inter-bedded with the sandstones as in laminated sands, the shale barriers could form effective seal/separation between the sand layers. High permeable sand layers in contact with the water zone are often times responsible for the high water influx and these could be isolated by cement squeeze operation during workover to minimize the level of water production. In some cases, an entire perforation is completely squeezed off and the well re-completed higher up the structure away from the oil-water-contact (OWC). Cement squeeze operation may not be feasible or effective if adequate zonal isolation is not possible due to absence of shale barrier streaks. In such cases, application of fluid mobility modifiers could be considered in the form of conformance technology, described next.

Conformance Control Technology

Reservoir conformance is the process of applying various methods and technologies to a reservoir or wellbore to reduce or control unwanted water or gas production so that recovery efforts are efficiently enhanced and operator profitability improved. Several water production control chemicals have been developed for different applications. In some cases, matrix fracture sealants are injected into the formation, if the production of unwanted water is traceable to fracture paths. Other applications include selective relative permeability modifier that is capable of reducing relative permeability to water without affecting relative permeability to the oil and/or gel treatment. While several publications have appeared giving case histories of field applications of these technologies, the long-term effect on reservoir properties and overall well performance remains a controversy to industry operators. Ehlig-Economides et. al (1996) observed gel treatment to build a coning barrier has been found to be ineffective and uneconomical in certain fields.

Total Penetration Approach

In this approach the perforation interval is extended to cover the entire oil zone and into the bottom water zone. The aim is to maintain radial flow of fluid and so avoid cone development and the attendant oil bypass. Production of water starts immediately and so requires increased water handling facilities. As production increases, over time, the tendency for cone development is inevitable (Ehlig-Economides, et. al., 1996). Also, the co-mingled production of high water volume and oil in one string could create unwanted environmental problem caused by the disposal of the contaminated water. All or most of the above solutions addresses only one aspect of the two-prong problem of water coning namely; (1) increased water cut and water handling problems and; (2) bypassed oil in the reservoir as a result of water coning/cresting around the wellbore.

3. Excessive Wax Deposition

3.1. Overview

Various tools and technologies are available in oil industry for controlling undesirable water production, each of these technologies has been developed for certain types of water production problems, whereas appropriate selection of the water control technology depends on the correct identification and diagnosis of the water production problem source. Hence, water production problems often are not properly diagnosed. In fact, incorrect, inadequate, or lack of diagnosis has been cited as one of the major reasons that water control treatments have been ineffective. Proper diagnostic techniques significantly enhance success of traditional treatments, both technically and.

Today's petroleum products fall into one of three categories: light distillates (liquefied petroleum gas, gasoline, and naphtha), middle distillates (kerosene and diesel), or heavy distillates and residuum (heavy fuel oil, lubricating oils, wax, and asphalt).

As the supply of the more favourable light and middle distillates are depleted, the energy industry is forced to look into the conversion of the heavier fraction of the crude to meet the increasing energy demand around the world. These heavier fractions of crude, however, contain a significant concentration of paraffin waxes, asphaltene as well as numerous other macromolecules that require treatment before going to market. These petroleum macromolecules have the ability to cause severe, if not hazardous, problems if left untreated.

As we become more and more dependent on heavy and extra heavy crude oils for energy, the control of these macromolecules becomes a challenge for engineers. One of the most common problems in the production of heavy crude involves the formation of paraffin wax deposition in pipelines. The inner surface of the pipeline becomes fouled with these paraffin deposits, which reduces flow diameter, decreases overall throughput, and results in a higher pressure drop when crude is pumped through the pipeline. This leads to greater losses in pressure.

The transportation of heavy crude from its production location to the refinery can require a substantial network of pipelines. These pipeline networks become even more important when it comes to the success of newly developing undersea, off shore energy projects. The colder conditions under water promote deposition and presents challenges for maintenance and replacement. Hence, the build-up of paraffin waxes in these pipelines can cause great losses in profit and efficiency.

The presence of asphaltene adds another level of difficulty for wax treatment because these structures are almost always found in association with waxes when they are retrieved from wells, storage tanks or pipelines (Becker 1997). Paraffin wax deposition could be reduced by increasing the flow velocity of crude through pipelines since less time in the pipeline means less time for the deposits to form. However, increasing the fluid velocity increases the likelihood of asphaltene deposition. To resolve paraffin wax deposition, sometimes it is also necessary to consider emulsions, dispersed solids, and inorganic scales (Becker 1997). Thus, it can be very difficult and costly to maximize production by only treating one but not the other influencing factors. It is up to the engineers and scientists to seek an economically viable solution that reduces the formation of paraffin wax without increasing the concentration of other macromolecules.

Effects of Paraffin Deposition

Some of the general effects include:

1. A decrease in pipeline cross-sectional area due to the presence of deposits, which then limits throughout and operating capacity.
2. An increase in capital investment due to higher maintenance cost, the cost for remedial action, and prevention.
3. Placing additional strain on pumps, consuming more energy, and requiring additional investment for replacing pumps.
4. A loss of production due to complete blockage of pipes, which lead too costly periodic production shutdowns for maintenance and replacement.

3.2 Methodology

Key Parameters

There are three important wax related concepts which must be mentioned. These are Wax Appearance Temperature (WAT), pour point and wax content. High WAT and high pour point are two factors which indicate potential wax-related problems. The phenomenon of wax appearing as a solid phase in a petroleum fluid is described by different synonymic terms in the literature. These synonymic terms are Wax Appearance Temperature (WAT), cloud point, Wax Appearance Point (WAP), Wax Formation Temperature (WFT) and Wax Precipitation Temperature (WPT).

The term Wax Appearance Temperature (WAT) will consistently be used further on in this work. WAT is the temperature where wax starts to drop out in the liquid bulk fluid in an observable amount and may deposit on the surface of the pipe wall. In other words, WAT tells whether wax will deposit in a pipeline and approximately where this appears. In the ASTM (American Society for Testing and Materials) methods proposed for transparent liquids (ASTM D2500/IP219) it is stated that cloud point describes the appearance of wax crystals in any petroleum fluid and by any detection system. This term should strictly be used to describe the appearance of a "cloud" of wax crystals visible, or an optical detector, upon cooling under prescribed conditions. ASTM also states that Wax Appearance Point (WAP) describes the appearance of wax crystals in dark colored distillate fuels (wax appearing in the range -26 to +2°C), as observed visually in a specified sample tube and under specified illumination. Hence, this WAP definition only applies to the specific conditions under this ASTM method.

WAT depends on the sample quality and the measurement method. It is difficult to measure WAT and experience is very important. Cross-Polar Microscopy (CPM), Differential Scanning Calorimetry (DSC), polarization microscopy and viscometry are some of the methods used for measuring WAT. Pour point is considerably lower temperature than WAT, and it is described as the lowest temperature at which a liquid remains pourable. In oils the pour point is generally increased by high paraffin content. Waxes will start to precipitate as temperature decreases, and at some point the precipitates accumulate to the point where the fluid no longer can flow. One definition of the wax content is that it is the amount of wax that will precipitate in excess acetone at approximately -25 °C. Normally the wax content in the North Sea oils range from 0 to 15 weight percent. Wax content is a critical input to a wax deposition prediction.

Temperature-driven Wax Deposition – Gradient Survey

As the produced fluid enters the well, the reservoir pressure and temperature gradually decreases. At the wellhead the fluid normally has high pressure and a moderate temperature. Crude oil from the reservoir will typically flow into the production pipeline around 60°C. As crude oil flows through the subsea pipeline, the temperature falls along the axis and the radius of the pipe. This temperature driven fluid cooling process occurs due to heat loss to the cold seawater surrounding the pipeline.The temperature and pressure gradient survey of the well yields information about the degree of wax deposition. With this lead, the necessary remedial action can be implemented to restore the health of the well.

3.3 <u>Analysis & Interpretation</u>

In this project work, well B(1) of field X-1 was taken into consideration. The data used here has been referred in the Appendix 7 at the end of this work.

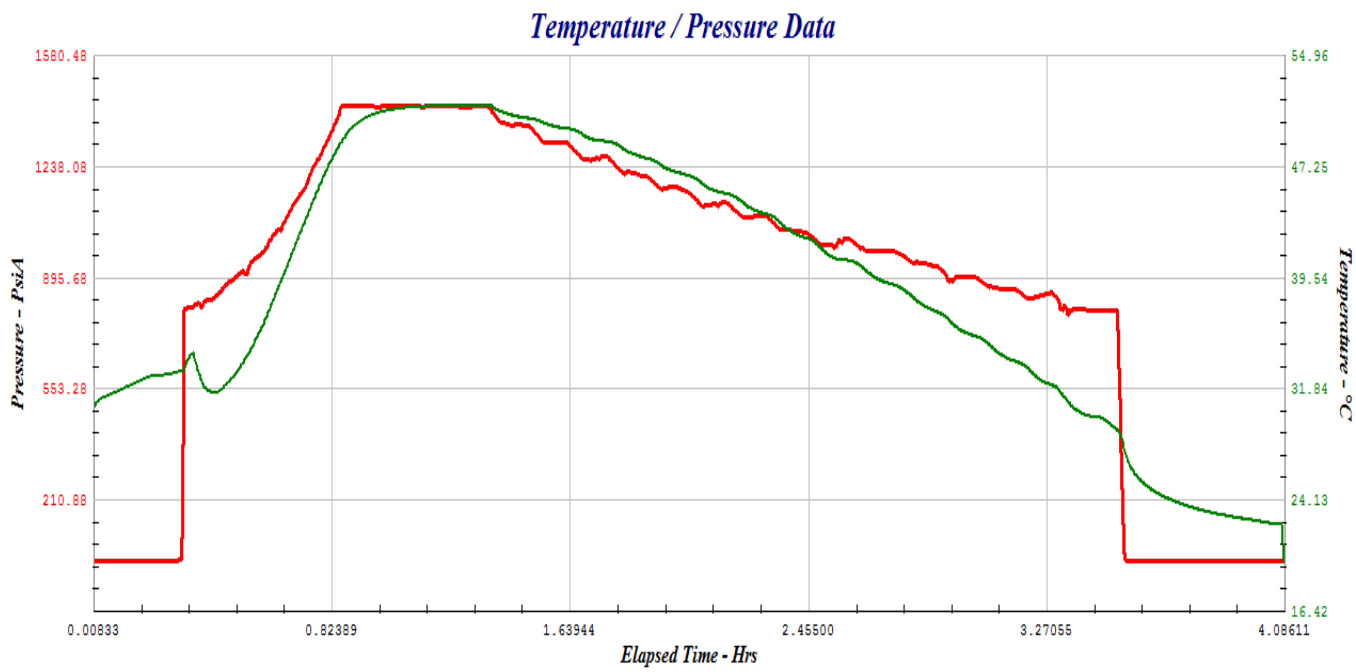
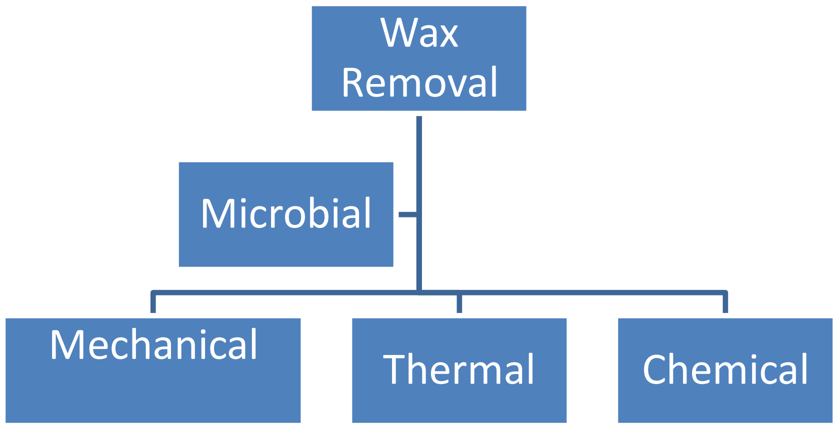


Figure 13: Gradient survey of well B(1)

The gradient survey clearly indicates the temperature drops and correspondingly the presence of wax deposition in the well. The above is correlated with the production history of the well which shows that due to mechanical action of scrapping, the oil production rate increases to the producing maximum until the wax deposition resurfaces.

3.4 Conclusion & Recommendations

A wax inhibition and removal program is generally of three types – mechanical, thermal and chemical. Microbial remediating techniques also have been under discussion in the oil & gas industry, but are outside the scope of this project work.



Mechanical Methods

Scrapers and cutters are used extensively to remove wax deposits from tubing because they can be economical and result in minimal formation damage. Scrapers may be attached to wireline units, or they may be attached to sucker rods to remove wax as the well is pumped. Deposits in surface pipelines can be removed by forcing soluble or insoluble pigs through the lines. Soluble pigs may be composed of naphthalene or microcrystalline wax. Insoluble pigs are made of plastic or hard rubber.

Another method of mechanical intervention to prevent deposition is the use of plastic or coated pipe. Low-friction surfaces make it more difficult for wax crystals to adhere to the pipe walls. Deposition will still occur if conditions are highly favourable for wax precipitation, and deposits will grow at the same rate as for other pipes once an initial layer of material has been laid down; therefore, the pipe and coating system must be capable of withstanding one of the other methods of wax removal.

Thermal Methods

Because wax precipitation is highly temperature dependent, thermal methods can be highly effective both for preventing and removing wax precipitation problems. Prevention methods include steam- and electrical-heat tracing of flow lines, in conjunction with thermal insulation. Thermal methods for removing wax deposition include:

- Hot oiling
- Hot watering

Hot water treatments cannot provide the solvency effects that hot oiling can, so surfactants are often added to aid in dispersion of wax in the water phase. Surfactants are discussed under chemical methods.

Hot oiling is one of the most popular methods of deposited wax removal. Wax is melted and dissolved by hot oil, which allows it to be circulated from the well and the surface producing system. Hot oil is normally pumped down the casing and up the tubing; however, in flowing wells, the oil may be circulated down the tubing and up the casing. There is evidence that hot oiling can cause permeability damage if melted wax enters the formation.

Higher molecular-weight waxes tend to deposit at the high-temperature bottom end of the well. Lower molecular-weight fractions deposit as the temperature decreases up the wellbore. The upper parts of the well receive the most heat during hot oiling. As the oil proceeds down the well, its temperature decreases and the carrying capacity for wax is diminished. Thus, sufficient oil must be used to dissolve and melt the wax at the necessary depths.

Chemical Methods

The types of chemicals available for paraffin treatment include:

- Solvents
- Pour point depressants (Wax crystal modifiers)
- Dispersants

- Surfactants

Solvents can be used to treat deposition in production strings and also may be applied to remediate formation damage. Although chlorinated hydrocarbons are excellent solvents for waxes, they generally are not used because of safety and processing difficulties they create in the produced fluid. Hydrocarbon fluids consisting primarily of normal alkanes such as condensate and diesel oil can be used, provided the deposits have low asphaltene content. Aromatic solvents such as toluene and xylene are good solvents for both waxes and asphaltenes. Solvents are mostly used in large batch treatments.

Wax crystal modifiers act at the molecular level to reduce the tendency of wax molecules to network and form lattice structures within the oil. Wax crystal modifiers which are used to prevent wax deposition, reduce oil viscosity and lower the wax gel strength are only effective when used continuously. Since they work at the molecular level they are effective in concentrations of parts per million, as opposed to hot oil or solvents, which must be applied in large volumes. Wax crystal modifiers have a high-molecular-weight and as a result they have high pour points, so their use can be limited in cold climates.

Pour-point depressants (PPDs) are designed to be cost-effective methods to improve cold-flow properties of crude and other fuel oils to remain primarily as a fluid. PPDs accomplish this task by modifying the size and shape of wax crystals and inhibit the formation of large wax crystal lattices (Wang et al. 1999). Wang, Flamberg, and Kikabhai determined that PPDs typically have three components:

1. A wax-like paraffinic part composed primarily of linear alkyl chains of 14 to 25 carbon atoms long, which co-crystallizes with the oil's wax-forming components
2. A polar component to limit the degree of co-crystallization
3. A primary component composed of polymers which, when attached to the wax crystal, will sterically hinder growth of large crystals

The mechanism to prevent agglomeration primarily involves the structure of the PPDs to disrupt the crystal habit of wax crystals (Hemant et al. 2008).The structures involved in this process are: the pendant chains to co-crystallize with the wax and the polar end groups which are responsible for disrupting the orthorhombic crystal structure into a compact pyramidal form. This process prevents the crystals from agglomerating and forming a gel-like structure to deposit on the pipeline surface, as can be seen from the figure below.

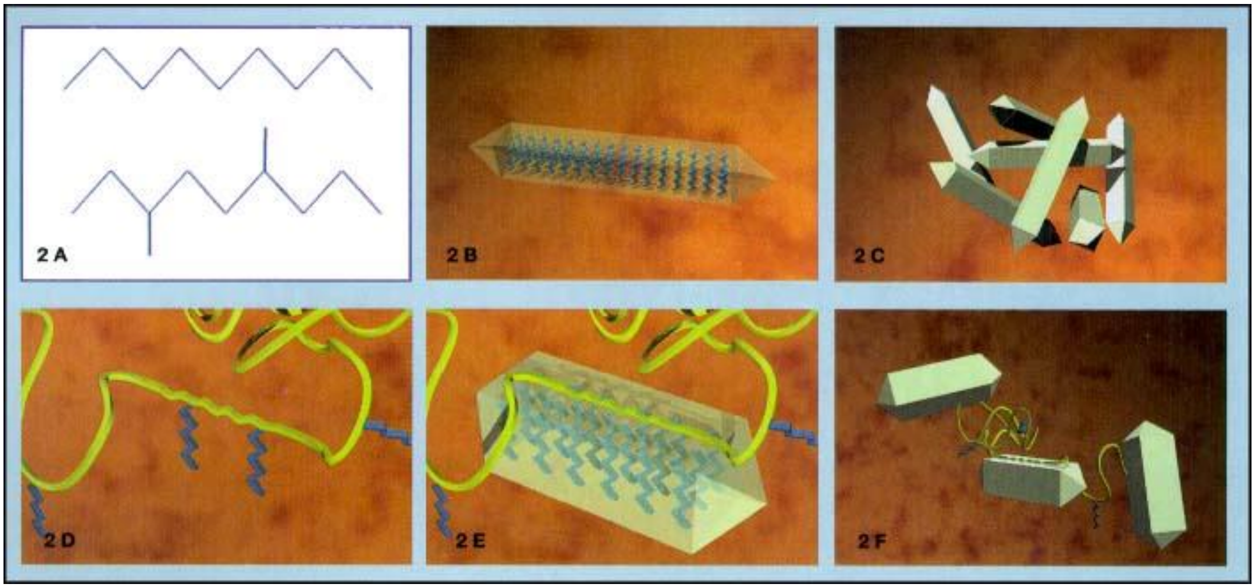


Figure 14: PPD Inhibition mechanism of wax modification.
2a) Chemical structure of wax 2b) Crystal shape of wax structure
2c) Crystal structure of growing wax lattice 2d) Polymeric Additive with wax-like components
2e) Co-crystallization of wax and PPD 2f) sterically hindered wax structure

Dispersants are a type of surfactants that helps disperse the wax crystals into the produced oil or water. This dispersing of the wax crystals into the produce oil or water helps prevents deposition of the wax and also has a positive effect on the viscosity and gel strength. Dispersants can help break up deposited wax into particles small enough to be carried in the oil stream. To prevent wax deposition dispersants must be used continuously. To remediate deposited wax, dispersants can be used continuously or in batch treatments. Dispersants generally have a very low pour point making their use suitable for cold climates. These chemicals are used in low concentrations and can be formulated in both aqueous and hydrocarbon solutions, making them relatively safe and inexpensive.

Surfactants are a general class of chemicals that are most often used to clean vessels, tanks, pipes, machinery or any place where wax may deposit. Surfactants or dispersants can also be used in combination with hot oil and water treatments.

Proposed Chemical Injection

The current practice used to date in well B(1) for removing paraffin/wax deposition is regular scraping and hot oil circulation with WDM (Well De-waxing material), circulated down the 2 7/8' tubing. This type of control requires a lot of monitoring and well interventions, increasing the risk of stuck tool strings, as well as increase in workover requirements, which can result in production loss due to formation damage. The gradual wax precipitation in the self-flowing wells generates sufficient friction to stop the natural flow of the well. Rod pumping wells end up pumping dry due to the gradual buildup of wax in the tubing and around the rods.

In this project work, considering the above limitations, the chemical injection method is proposed for restoring the health of the well.

Chemical injection is the process of injecting fluid chemicals into the production stream of a well to control corrosion and harmful deposits in the tubing and tubing accessories during production. In a typical chemical-injection installation, a chemical-injection mandrel with a chemical-injection valve is installed as part of the production tubing string. A chemical-injection line may be run from the chemical-injection mandrel to the surface to act as a conduit for the injection fluid. In other installations, the injection chemical is pumped down the tubing/casing annulus and into a port in the chemical-injection mandrel. Reverse-flow check valves are installed at the point of injection to prevent flow from the production tubing from entering the injection flow path. A high-pressure pump, capable of overcoming tubing pressure, is installed on the surface to pump the chemical injection fluid into the downhole point of injection in the production stream.

- **Trichloroethylene - Xylene binary system**

Xylene-based PPDs form structures with segments that interact with the developing wax crystals to inhibit crystal formation (Bello et al. 2005). A specific xylene based PPD which exhibits a substantial effect as a pour-point depressant is trichloroethylene-xylene (TEX) binary system (Bello et al .2006).This additive utilizes one or more postulated mechanisms including nucleation, adsorption, co-crystallization and improved wax solubility in the reduction of large wax crystals (Bello et al .2006). The trichloroethylene compound contains an ionic pair of electrons which facilitates greater adsorption of the inhibitor molecules onto the wax crystal networks and prevents the interlocking of the wax network (Bello et al. 2005).

The TEX binary system has the ability to form a stable suspension in crude oil, which results in the inhibition of wax crystal formation. (Bello et al. 2005). As a result, this additive has a greater application on various different crudes and a tremendous economic benefit in the inhibition of wax-crystal formation.

- **Sulphur Trioxide**

It is known that while the precipitation and formation of paraffins and asphaltenes is at the core of the fouling problem, it is the accumulation of such compounds that affects the flow characteristics of fluids in pipelines. The cause of such accumulation is attributed to irregularities of, or specific physical properties of, the inner surface of the pipeline (Charles and Marcinew 1986).

After the inside surface of the pipeline is thoroughly washed, it is treated with sulphur trioxide to create a strongly water-wet surface (Goncharenko et al. 1978). It is important to note that the "highly" water-wet properties of the material are only observed on the inner surface of the steel. This highly hydrophilic surface creates a thin layer of water that is held close to the surface (Bernadiner 1993) and prevents any already formed paraffins or asphaltenes from accumulating on the surface.

Another method of application is the introduction of an aqueous solution containing dissolved sulphur trioxide to the pipeline (Bernadiner 1993). The dual responsibility this solution has is as a surface cleaner of the pipeline's interior and a wetting agent to create the lubricating layer of water on the inner surface of the pipeline (Bernadiner 1993). Work has been done regarding surfactants to accomplish the cleaning job the solution must accomplish. Also, these surfactants can act to emulsify the oil and water in the production line, thus lowering the rate of formation of paraffin deposits (Bernadiner 1993).

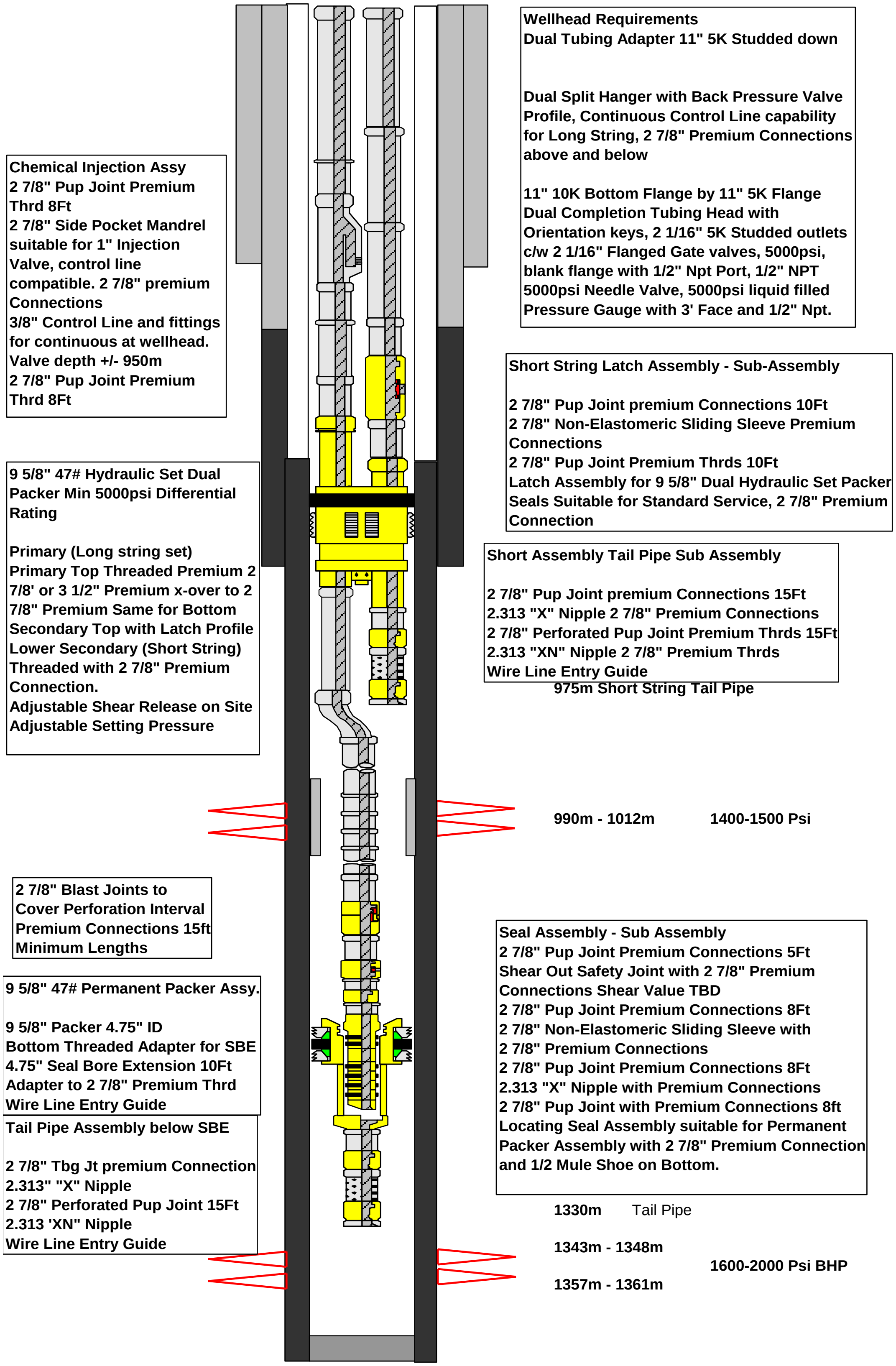


Figure 15: Proposed dual completion of well B(1) with provision for Chemical Injection

4. Sand Production

4.1. Overview

Completing wells in high sanding environments raises several major risks that are not faced in more competent formations. In most cases, the risks and costs associated with remedial actions are significant in deep and high temperature regions.

The solid material which is produced from a well consists of formation fines and load bearing sand). The fines production, which cannot normally be prevented, is preferred over the production of load bearing sand. Sand production will create a problem if the surface equipment cannot handle it, if the sand blocks the tubing, or if the sand production detrimentally alters the formation (i.e. collapsed formation). Some well-known causes of sand production are listed below.

- ✓ **Onset of water production**

There are 4 reasons on why sand production is worsened by increasing water production:

- Capillary pressure holding sand grains are lost due to producing water.
- Flow frictional significantly increases due to more than one phase flow.
- High pressure gradient at the sandface due to higher flow rate for a desired net production.
- Water may dissolve cementing materials between sand grains.

- ✓ **Unconsolidated formation**

The cementation of sandstone is typically a secondary geological process and as a general rule, older sediments tend to be more consolidated than newer sediments. Unconsolidated formation refers to a formation in a fluid state. Grain to grain contacts are rare. Any attempt to produce formation fluid can result in production of large amounts of sand with fluid. Poorly consolidated sandstone formations usually have a compressive strength that is less than 1000 psi).

- ✓ **Reduction of pore pressure**

Some reservoirs are believed to aid in the support of overburden. Lowering the reservoir pressure creates an increasing amount of stress on the formation sand itself. Continuing reduction of reservoir pressure may cause the overburden to subside and crush a poorly consolidated formation and result in sand production and serious casing damage. As most reservoirs in this sequence are not supported by strong water drive, their pressures are declining quite fast with time and production.

- ✓ **High production rates**

The high production rate imposes excessive stresses on unconsolidated formations. If the stress exceeds the formation strength, sand production will commence. Increasing the production rate is usually done for a high water cut well, in order to maintain a desired rate of oil production. Above a said threshold rate, sand will be produced. However, most of the time, as the rate is below the economic rate, the wells have to endure with the sand production to be economic.

Some authors discussed the presence of sand arches around each perforation in the casing. An arch is a hemispherical cap of interlocking sand grains that is stable at constant drawdown and flow rate, preventing sand movement). Initial arch size was found to be a function of initial producing rate. The initial arch size increases with increasing initial production rate. Larger arches were resulted from higher flow rates. Changes in flow rate or production shut in may result in collapse of the arch, causing sand to be produced until a new arch form. It is also possible to relate sonic and density log data to estimate the maximum sand-free production rate from each arch. Arch faces must remain in place if no sand production is to occur.

Mechanism of Sand Production

The mechanisms of sand production are either grain by grain attrition or small masses of sand breaking away). Sand production may be divided into the following three categories.

- **Transient Sand Production**

This refers to a sand concentration declining with time under constant well production conditions. This is usually observed during clean-up flow after perforating, choke change, and water breakthrough.

- **Continuous Sand Production**

The tolerated sand cut level depends on operational constraints with regard to erosion, sand disposal, etc.

- **Catastrophic Sand Production**

Events where a high rate of sand influx occurs cause the well to suddenly die. For the transient and continuous sand production, some of the continuously produced sand settles inside the wellbore and increases the hold-up depth. However, it will take time for sand-up to occur due to less sand production, especially if the majority of the sand is transported to the surface. If all the sand can be carried out of the wellbore, no sand-up will occur and no sand control is required, provided that the surface facilities can handle and process the sand production.

4.2 Methodology

Formation Sand Sampling

The first step in gravel-pack design is to obtain a representative sample of the formation. Failure to analyse a representative sample can lead to gravel packs that fail because of plugging or the production of sand. Because the formation sand size is so important, the technique used to obtain a formation sample requires attention. With knowledge of the different sampling techniques, compensation can be made in the gravel-pack sand size selection, if necessary.

- **Produced samples**

A produced sample of the formation sand is easily contaminated before it reaches the surface. Although such a sample can be analyzed and used for the gravel-pack sand size determination, produced samples will probably have a smaller median grain size than the median of actual formation sand. The well's flow rate, produced fluid characteristics, and completion tubular design influence whether a particular size is produced to surface or settles to the bottom of the well. In many cases, the larger sand grains settle, so a sample that is produced to the surface has a higher proportion of the smaller-size sand grains. This is the reason that the surface sample is not a good representation of the various sizes of formation sand. Also, the transport of sand grains, through the production tubing and surface flow lines, may result in broken sand grains, causing the presence of more fine and smaller grains.

- **Bailed samples**

Samples collected from the bottom of a well using wireline bailers are also relatively easy to obtain, but these too are probably unrepresentative of the size of the actual formation sand. Bailed samples are generally biased to the larger-size sand grains, assuming that more of the smaller grains are produced to surface. Bailed samples also may be misleading in terms of grain size distribution. When closing the well in to obtain a sample, the larger sand grains settle to the bottom of the well first, and the smaller sand grains fall on top of the larger ones. This results in a sorting of the formation sand grains into a sample that is not representative the formation sand. The use of bailed samples may result in the design of larger than required gravel-pack sand that can result in sand production (small formation particles passing through the gravel pack) or plugging of the gravel pack (small formation particles filling the spaces between the gravel-pack sand grains).

Figure 16: Typical sand bailer

- **Sidewall core samples**

Sidewall core samples are obtained by shooting hollow projectiles from a gun lowered into the well on an electric line to the desired depth. The projectiles remain attached to the gun with steel cables, so that when the gun is pulled from the well, the projectiles are retrieved with a small formation sample inside. Taking sidewall core samples is generally included in the evaluation stages of wells in unconsolidated formations; these are the most widely used sample types for gravel-pack sand design. Although more representative than produced or bailed samples, sidewall core samples can also give imprecise results because the volume in each sidewall sample is small.

- **Conventional core samples**

The most representative formation sample is obtained from conventional cores. In the case of unconsolidated formations, rubber sleeve conventional cores may be required to assure sample recovery. Although conventional cores are the most desirable formation sample, they are not readily available in many wells because of the cost of coring operations. Coring in sand-producing formations is also plagued with poor recovery. If available, small plugs can be taken under controlled circumstances at various sections of the core for a complete and accurate median formation grain size and grain-size distribution determination.

Sieve Analysis

A sieve analysis is a laboratory routine performed on a formation sand sample for the selection of the proper-sized gravel-pack sand. A sieve analysis consists of placing a formation sample at the top of a series of screens that have progressively smaller mesh sizes downwards in the sieve stack. After placing the sieve stack in a vibrating machine, the sand grains in the sample will fall through the screens until encountering a screen through which certain grain sizes cannot pass because the openings in the screen are too small. By weighing the screens before and after sieving, the weight of formation sample, retained by each size screen, can be determined. The cumulative weight percent of each sample retained can be plotted as a comparison of screen mesh size on semi-log coordinates to obtain a sand size-distribution plot.

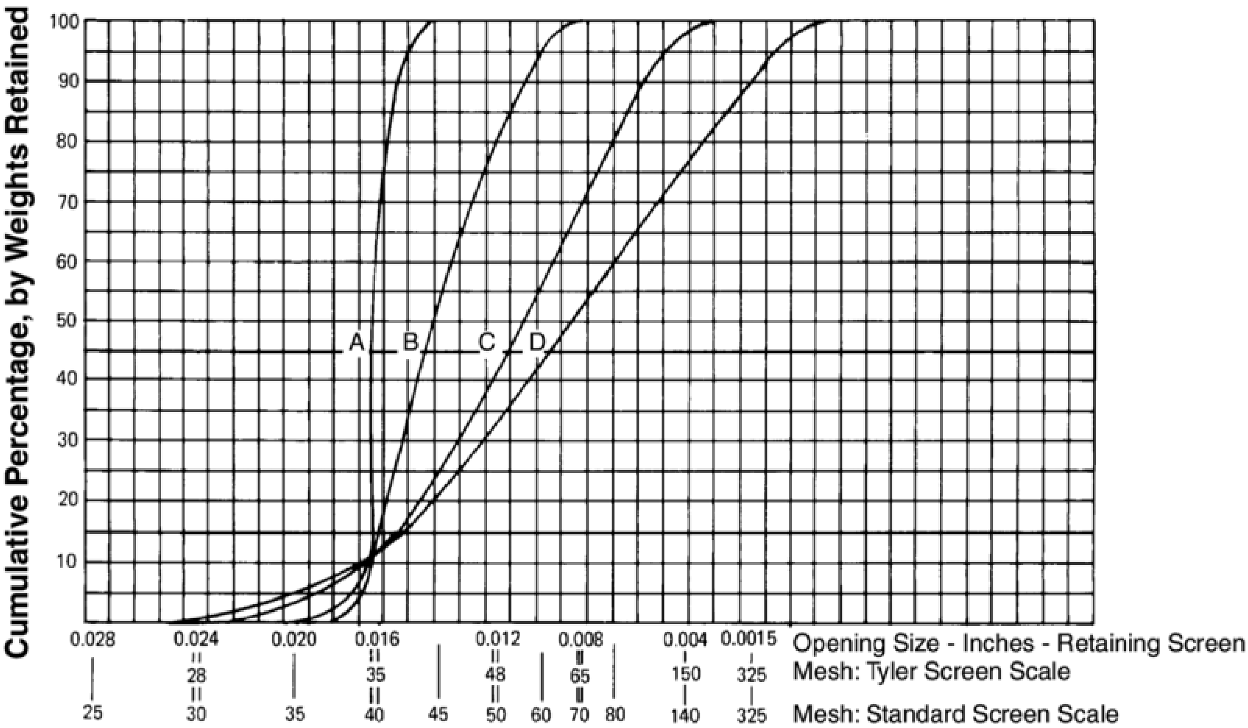


Figure 17: Sand size distribution plot from sieve analysis

Reading the graph at the 50% cumulative weight gives the median formation grain size diameter. This grain size, often referred to as d50, is the basis of gravel-pack sand size-selection procedures.

U.S. Series Mesh Size	Sieve Opening, in.	Sieve Opening, mm	U.S. Series Mesh Size	Sieve Opening, in.	Sieve Opening, mm
2.5	0.315	8.000	35	0.0197	0.500
3	0.265	6.730	40	0.0165	0.420
3.5	0.223	5.660	45	0.0138	0.351
4	0.187	4.760	50	0.0117	0.297
5	0.157	4.000	60	0.0098	0.250
6	0.132	3.360	70	0.0083	0.210
7	0.111	2.830	80	0.0070	0.177
8	0.0937	2.380	100	0.0059	0.149
10	0.0787	2.000	120	0.0049	0.124
12	0.0661	1.680	140	0.0041	0.104
14	0.0555	1.410	170	0.0035	0.088
16	0.0469	1.190	200	0.0029	0.074
18	0.0394	1.000	230	0.0024	0.062
20	0.0331	0.840	270	0.0021	0.053
25	0.0280	0.710	325	0.0017	0.044
30	0.0232	0.589	400	0.0015	0.037

Figure 18: Reference for mesh size and sieve openings in sieve analysis

If possible, a sample should be taken every 2 to 3 feet within the formation, or at least at every lithology change. The minimum size of the formation sample required for sieve analysis is 15 cm^3. Sieving can be performed either wet or dry. In dry sieving (the most common technique), the sample is prepared by removing the fines (i.e., clays) and drying the sample in an oven. If necessary, the sample is ground with a mortar and pestle to ensure individual grains are sieved rather than conglomerated grains. The sample is then placed in the sieving apparatus that uses mechanical vibration to assist the particles in moving through and on to the various mesh screens. Wet sieving is used when the formation sample has extremely small grain sizes. In wet sieving, water is poured over the sample while sieving to ensure that the particles do not cling together.

Gravel pack sand sizing

There have been several published techniques for selecting a gravel-pack sand size to control the production of formation sand. The most widely used sizing criterion1 provides sand control when the median grain size of the gravel-pack sand, D50 , is no more than six times larger than the median grain size of the formation sand, d50 . The upper case D refers to the gravel, while the lower case refers to the formation sand. The basis for this relationship was a series of core flow experiments in which half the core consisted of gravel-pack sand and the other half was formation sand. The ratio of median grain size of the gravel-pack sand and median grain size of the formation sand was changed over a range from 2 to 10 to determine when optimum sand control was achieved.

The experimental procedure consists of measuring the pack permeability with each change in gravel size and comparing it to the initial permeability. If the final permeability was the same as the initial permeability, it was concluded that effective sand control was achieved with no adverse productivity effects. If the final permeability was less than the initial permeability, the formation sand was invading and plugging the gravel-pack sand. In this situation, sand control may be achieved, but at the expense of well productivity.

In practice, the proper gravel-pack sand size is selected by multiplying the median size of the formation sand by 4 to 8 to achieve a gravel-pack sand size range, in which the average is six times larger than the median grain size of the formation sand. Hence, the gravel pack is designed to control the load-bearing material; no attempt is made to control formation fines that make up less 2 to 3% of the formation. This calculated gravel-pack sand size range is compared to the available commercial grades of gravel-pack sand. Select the available gravel-pack sand that matches the calculated gravel-pack size range or the smaller size if preferred size is unavailable.

Gravel Size, U.S. Mesh	Size Range, in.
8/12	.094–.066
12/20	.066–.033
20/40	.033–.017
40/60	.017–.0098
50/70	.012–.0083

Figure 19: Commercially available sand gravel-pack sand sizes

This technique is based solely on the median grain size of the formation sand with no consideration given to the range of sand grain diameters or degree of sorting present in the formation. The sieve analysis plot, discussed earlier, can be used to obtain the degree of sorting in a particular formation sample. A near vertical sieve analysis plot represents good sorting (most of the formation sand is in a very narrow size range) in comparison to a highly sloping plot, which indicates poorer sorting. A sorting factor, or uniformity coefficient, can be calculated as:

$$C_\mu = \frac{d_{40}}{d_{90}},$$

where,

- C_μ = sorting factor or uniformity coefficient,
- d_{40} = grain size at the 40% cumulative level from sieve analysis plot,
- d_{90} = grain size at the 90% cumulative level from sieve analysis plot.

If C_μ is less than 3, the sand is considered well sorted (uniform); from 3 to 5, it is non-uniform, and if greater than 5, it is highly non-uniform.

Gravel pack sand

The productivity of a gravel-packed well depends on the permeability of the gravel-pack sand and how it is placed. To ensure maximum well productivity, one should use high quality gravel-pack sand. API *RP 58*, Testing Sand Used in Gravel Packing Operations, establishes rigid specifications for acceptable properties of sands used for gravel packing. These specifications focus on ensuring the maximum permeability and longevity of the sand under typical well production and treatment conditions. The specifications define minimum acceptable standards for:

- Size and shape of the grains
- Amount of fines and impurities
- Acid solubility
- Crush resistance

Only a few naturally occurring sands are capable of meeting the API specifications without excessive processing. These sands are characterized by their high quartz content and consistency in grain size.

Gravel pack sand substitutes

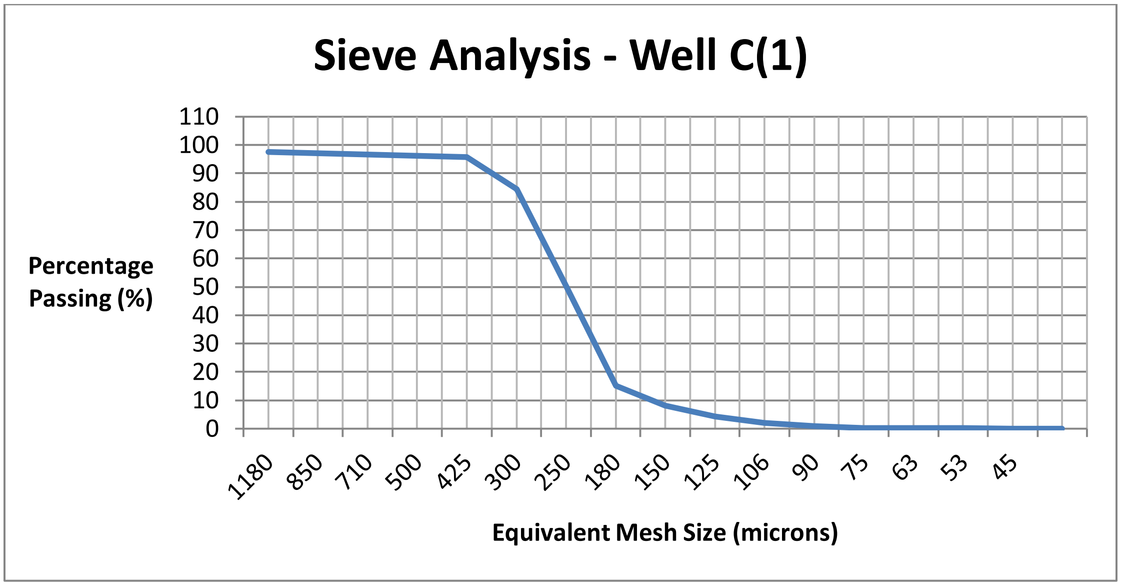
Although naturally occurring quartz sand is the most common gravel-pack material, many alternatives exist. These include:

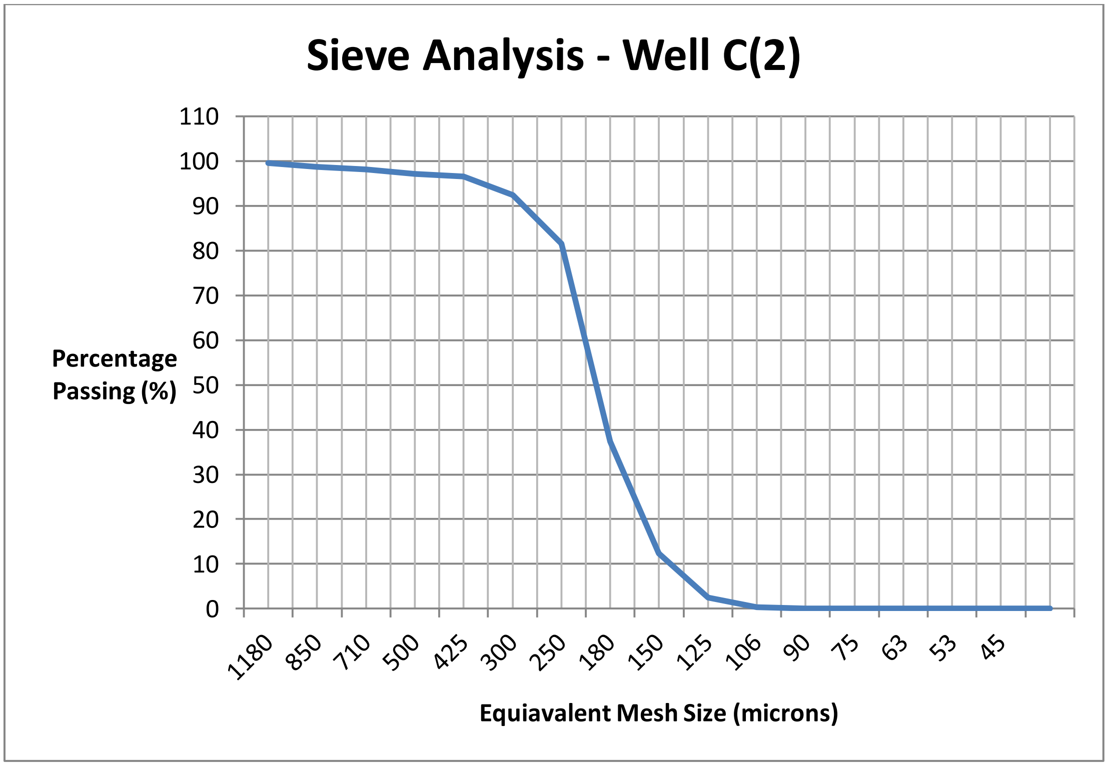
- Resin-coated sand
- Garnet
- Glass beads
- Aluminum oxides

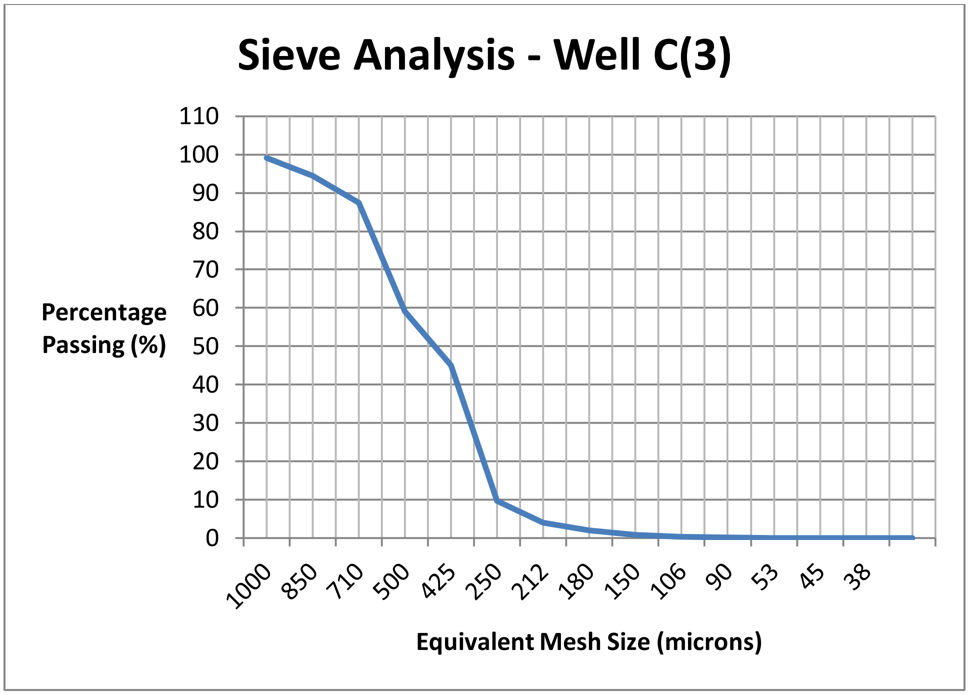
Each of these materials offers specific properties that are beneficial for given applications and well conditions. The cost of the materials ranges from 2 to 3 times the price of common quartz sand.

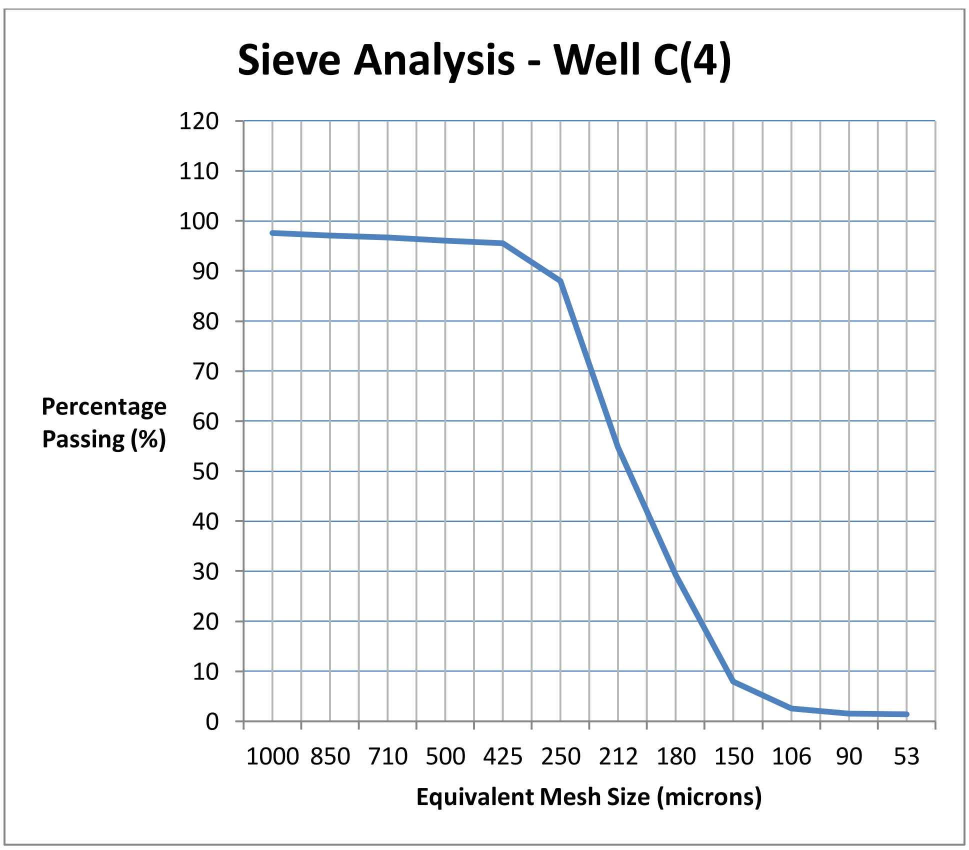
4.3 Analysis & Interpretation

In this project work, wells C(1) to C(4) of a X-2 field have been studied. The data used here has been referred in the Appendix 7 at the end of this work. Figures 20 to 23, in that order, show the sieve analysis of the respective wells.






Sieve Analysis - Well C(3)
Percentage Passing (%)
110
100
90
80
70
60
50
40
30
20
10
0
1000
850
710
500
425
250
212
180
150
106
90
53
45
38
Equivalent Mesh Size (microns)


Sieve Analysis - Well C(4)
Percentage Passing (%)
120
110
100
90
80
70
60
50
40
30
20
10
0
1000
850
710
500
425
250
212
180
150
106
90
53
Equivalent Mesh Size (microns)

Well	d_{50}	D_{50}	D_{50}	d_{40}	d_{90}	C_{μ}	Comment on Sorting
	(microns)	(microns)	(inches)				
C(1)	215	1290	0.050787	202	300	0.673333	Well-sorted
C(2)	172	1032	0.04063	165	265	0.622642	Well-sorted
C(3)	425	2550	0.100394	325	605	0.53719	Well-sorted
C(4)	195	1170	0.046063	190	250	0.76	Well-sorted

Table 3: Interpretation of sieve analysis results

4.4 Conclusion & Recommendations

The design objective for well screens is stoppage of sand infiltration without excessive reduction of flow capacity. In order to determine the proper gauge for well screens, as well as, the proper gravel pore space, the formation grain size must be known.

Without Gravel Pack

In this situation the sand control is the base on the bridging theory and slot openings must be sized in direct relationship to the formation sands. Sand bridges are formed across the slot opening when the slot opening is about 2 times the sand grain diameter, preventing further particle movement. If the size of the grains varies, retention of the larger particles causes smaller particles to bridge behind them. To achieve stable bridges the individual sand grains should bridge on, rather than in, the slot openings. In formations with relatively coarse-grained, high-permeability sands, controlling sand and maintaining the well's productivity is successful when a certain amount of formation sand can be tolerated. In stand-alone screen completions without the use of back-surging or pump-in treatments, the finer particles are not effective removed from the sand-face of the near-wellbore sand mass.

For sands with a broad size distribution, a generally accepted guideline for designing a screen is to specify a slot width that is 2 times as large as the 10 percentile grain diameter. This sizing allows the finer particles to be produced, resulting in a natural gravel pack formed from the larger sand grains. For more uniform sands, screen openings equal to the 10-15 percentile formation sand diameters should be used. For a good result for non-uniform fine sand, we can take the 40 percentile sand diameter analysis. The recommended slot opening can be read off the horizontal scale.

With Gravel Pack

Gravel packing is probably the most popular mechanical sand-control technique used in water, oil and gas wells. The gravel pack stabilizes the borehole and filters the formation sand from the flow, while producing only very fine particles that can move through the gravel pack. Screens or slotted liners used in combination with a gravel pack function as a gravel retention device and need a different design. Ideally, slots should be as wide as possible while retaining gravel without restricting flow of fluids and interstitial fines. The loss of even a small amount of gravel may have a negative effect on the completion. Therefore, slot openings need to be sized for complete gravel retention. Proper sizing can be determined from sieve analysis of the gravel.

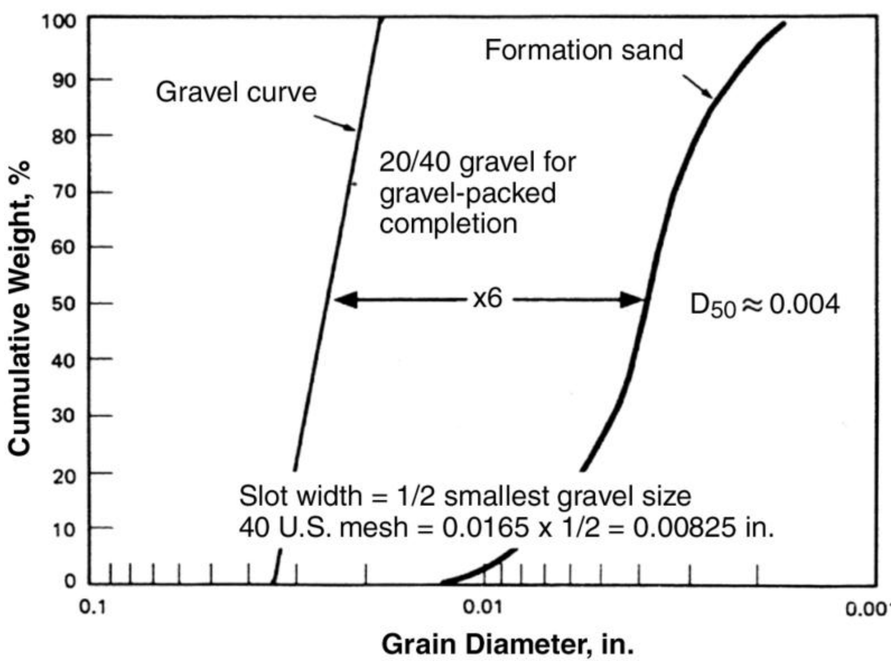


Figure 24: Example of a gravel pack design

The slot should not be wider than 50% to 70% of the smallest gravel-size diameter to avoid production of gravel. Because the flow capacity of screens and slotted liners are high, sizing the slot width on the low side will not restrict well productivity and will tend to avoid production of gravel.

5. Conclusion

In this project work, the consideration of wells with high water-cut, excessive wax deposition and sand production has been made. The sicknesses were identified by following a proper methodology, following which the identified sickness was analyzed and interpretations were made. Recommendations addresses in this project are with respect to the sicknesses of high water-cut through coning and channeling prevention, excessive wax deposition via chemical injection treatment, and sand production using properly designed gravel pack.

6. Future Scope

The analysis of a sick well is highly contextual, both in terms of a well's condition as well as the remedy applied to restore normal health. In this work, we have considered the three key areas of improvement in a well with high water-cut, excessive wax deposition, and sand production. Other such areas include corrosion, scale formation, migration of fines, emulsion formations, development of water blocks and among others, bacterial plugging. This work can be extended by incorporating the above in some capacity as well, so as to make it a comprehensive reference for any petroleum engineer dealing with the problem of analyzing sick wells.

7. Appendix

7.1 High Water-cut

The contour map of the wells A(1) to A(10) for the considered work is shown below. The production histories including the WOR data, and parameters to construct the water control diagnostic derivative plots is also provided.

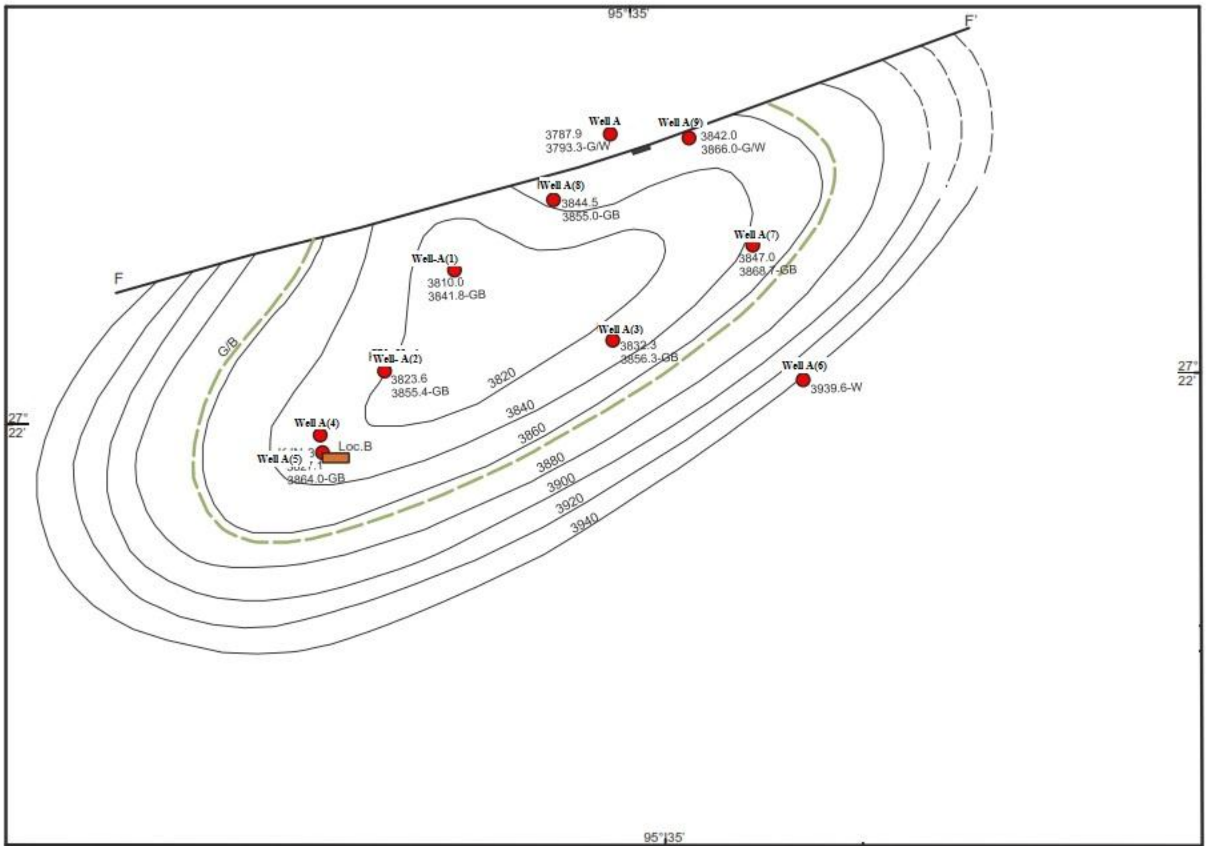


Figure 25: Contour map of field showing wells A(1) to A(10)

Production Days	Cumulative Days	Oil Rate	Water Rate	WOR	WOR'	WOR'
5.10	5.10					
20.80	25.90	30.1111111	0	0	0	0
30.00	55.90	56	0	0	0.000557	0.000557
30.70	86.60	120.645161	2.06451613	0.017112	-2.5E-05	
30.00	116.60	124.333333	2.03333333	0.016354	0.000244	0.000244
31.00	147.60	125.419355	3	0.02392	0.000402	0.000402

31.00	178.60	123.7	4.5	0.036378	0.002938	0.002938
28.00	206.60	120.809524	14.3333333	0.118644	0.000633	0.000633
31.00	237.60	122.483871	16.9354839	0.138267	-0.001	
30.00	267.60	131.333333	14.2380952	0.108412	0.002206	0.002206
31.00	298.60	122.967742	21.7419355	0.17681	0.000409	0.000409
30.00	328.60	120.4	22.7666667	0.189092	-0.00019	
31.00	359.60	122.290323	22.3870968	0.183065	-0.00027	
31.00	390.60	123.166667	21.5333333	0.174831	0.001971	0.001971
30.00	420.60	113.064516	26.4516129	0.233951	-0.00085	
31.00	451.60	113.793103	23.6206897	0.207576	0.000677	0.000677
30.00	481.60	111.6	25.4333333	0.227897	0.000697	0.000697
31.00	512.60	111.193548	27.7419355	0.249492	-0.00255	
31.00	543.60	117.366667	20	0.170406	-0.0005	
28.00	571.60	118.032258	18.4516129	0.156327	-9.5E-05	
31.00	602.60	118.75	18.2142857	0.153383	0.000544	0.000544
30.00	632.60	113.642857	19.2857143	0.169705	-0.00382	
31.00	663.60	119.612903	6.12903226	0.051241	-0.00036	
30.00	693.60	120.966667	4.9	0.040507	-1.8E-05	
31.00	724.60	121.16129	4.83870968	0.039936	-1.4E-05	
31.00	755.60	118.133333	4.66666667	0.039503	0.00014	0.00014
30.00	785.60	118.806452	5.19354839	0.043714	-3.2E-05	
31.00	816.60	117.064516	5	0.042711	0.000494	0.000494
30.00	846.60	120.482759	6.93103448	0.057527	-0.00045	
31.00	877.60	119.354839	5.19354839	0.043514	-1.8E-05	
31.00	908.60	117.133333	5.03333333	0.042971	0.001626	0.001626
29.00	937.60	111.677419	10.0645161	0.090121	0.000158	0.000158
31.00	968.60	112.387097	10.6774194	0.095006	0.01108	0.01108
30.00	998.60	91.75	39.2142857	0.427404	-0.00156	
31.00	1029.60	95.9354839	36.3548387	0.378951	-0.0073	
30.00	1059.60	99.7333333	15.9666667	0.160094	-0.00372	
31.00	1090.60	114.258065	5.12903226	0.04489	0.006121	0.006121
31.00	1121.60	94.9	22.2666667	0.234633	-0.00309	
30.00	1151.60	100.16129	14.2258065	0.142029	-1.6E-05	
31.00	1182.60	100.741935	14.2580645	0.141531	0.003273	0.003273
30.00	1212.60	92.3333333	22.1333333	0.239711	0.000579	0.000579
31.00	1243.60	90.6451613	23.3548387	0.257651	-0.00166	
31.00	1274.60	92.5	19.0666667	0.206126	0.001511	0.001511
28.00	1302.60	87.7741935	21.8064516	0.248438	-0.00067	
31.00	1333.60	91.1612903	20.7419355	0.22753	-0.00027	
30.00	1363.60	91.8275862	20.137931	0.219302	0.000138	0.000138
31.00	1394.60	94.0645161	21.0322581	0.223594	0.000456	0.000456
30.00	1424.60	90.3333333	21.4333333	0.237269	-3.4E-05	
30.90	1455.50	91.7741935	21.6774194	0.236204	-0.00061	
31.00	1486.50	91.9333333	19.9666667	0.217186	0.002263	0.002263
30.00	1516.50	86.6774194	24.7096774	0.285076	-0.00017	

31.00	1547.50	86.7419355	24.2580645	0.279658	0.00178	0.00178
30.00	1577.50	82.6666667	27.5333333	0.333065	0.011072	0.011072
31.00	1608.50	64.7741935	43.8064516	0.676295	-0.00054	
31.00	1639.50	64.4333333	42.5	0.659596	0.005959	0.005959
28.00	1667.50	57.0645161	47.1612903	0.826456	0.002004	0.002004
31.00	1698.50	55.5806452	49.3870968	0.888566	0.003714	0.003714
30.00	1728.50	62	62	1	0.015484	0.015484
31.00	1759.50	50	74	1.48	0	0
30.00	1789.50	50	74	1.48	0	0
31.00	1820.50	50	74	1.48	0	0
30.90	1851.40	50	74	1.48	0	0
30.00	1881.40	50	74	1.48	0.000787	0.000787

Table 4: Production history of Well A(1)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
0.90	0.90	46.70	0.00		
1.60	2.50	42.50	0.00	0	
1.00	3.50	38.00	0.00	0	0
3.00	6.50	42.60	0.00	0	0
15.70	22.20	36.60	0.00	0	0
30.00	52.20	32.10	0.00	0	0
27.90	80.10	31.70	0.00	0	0
31.00	111.10	30.10	0.00	0	0
31.00	142.10	26.00	0.00	0	0
29.00	171.10	29.70	0.00	0	0
31.00	202.10	27.20	0.00	0	0.001075
30.00	232.10	24.80	0.80	0.032258	0.001713
31.00	263.10	24.60	2.10	0.085366	
30.00	293.10	24.90	1.10	0.044177	4.12E-05
31.00	324.10	24.20	1.10	0.045455	
31.00	355.10	24.60	1.10	0.044715	
30.00	385.10	24.10	0.00	0	0.001317
31.00	416.10	24.50	1.00	0.040816	0.000272
30.00	446.10	24.50	1.20	0.04898	
31.00	477.10	25.10	1.10	0.043825	
31.00	508.10	24.80	0.00	0	0.001537
27.00	535.10	26.50	1.10	0.041509	
31.00	566.10	28.30	1.10	0.038869	
30.00	596.10	28.90	1.10	0.038062	0.001138
31.00	627.10	30.00	2.20	0.073333	
30.00	657.10	30.10	2.20	0.07309	0.000124
31.00	688.10	27.30	2.10	0.076923	
31.00	719.10	28.60	0.00	0	0.002537
30.00	749.10	28.90	2.20	0.076125	
31.00	780.10	24.40	1.30	0.053279	

30.00	810.10	28.40	1.10	0.038732	0.000714
31.00	841.10	23.00	1.40	0.06087	
31.00	872.10	23.60	1.10	0.04661	6.35E-05
28.00	900.10	24.80	1.20	0.048387	0.001505
31.00	931.10	24.20	2.30	0.095041	
30.00	961.10	31.60	2.30	0.072785	
31.00	992.10	24.00	1.50	0.0625	0.001022
29.30	1021.40	23.80	2.20	0.092437	0.000124
16.00	1037.40	23.30	2.20	0.094421	0.013192
2.00	1039.40	29.80	3.60	0.120805	
14.00	1053.40	22.10	0.00	0	0.003342
31.00	1084.40	22.20	2.30	0.103604	
31.00	1115.40	24.00	0.00	0	0
28.00	1143.40	25.90	0.00	0	0
31.00	1174.40	26.10	0.00	0	0
30.00	1204.40	26.50	0.00	0	0
31.00	1235.40	26.10	0.00	0	0.001003
30.00	1265.40	29.90	0.90	0.0301	0.000186
13.00	1278.40	36.90	1.20	0.03252	0.000464
31.00	1309.40	40.50	1.90	0.046914	
30.00	1339.40	40.10	1.70	0.042394	0.000111
31.00	1370.40	48.00	2.20	0.045833	
30.00	1400.40	51.90	2.20	0.042389	0.000416
31.00	1431.40	39.80	2.20	0.055276	
31.00	1462.40	39.10	2.00	0.051151	0.000232
29.00	1491.40	31.10	1.80	0.057878	0.000638
31.00	1522.40	30.90	2.40	0.07767	1.36E-05
30.00	1552.40	33.30	2.60	0.078078	9.94E-05
31.00	1583.40	34.50	2.80	0.081159	0.000803
30.00	1613.40	32.30	3.40	0.105263	0.000494
31.00	1644.40	28.20	3.40	0.120567	
31.00	1675.40	29.70	3.30	0.111111	
30.00	1705.40	29.60	3.20	0.108108	0.000158
31.00	1736.40	29.20	3.30	0.113014	
30.00	1766.40	30.40	3.40	0.111842	0
31.00	1797.40	30.40	3.40	0.111842	0.00319
31.00	1828.40	54.10	11.40	0.210721	
25.00	1853.40	27.60	3.20	0.115942	
31.00	1884.40	24.80	2.30	0.092742	
30.00	1914.40	26.30	2.30	0.087452	0.001471
31.00	1945.40	24.80	3.30	0.133065	
30.00	1975.40	25.40	3.20	0.125984	
31.00	2006.40	28.00	3.00	0.107143	0.000428
29.30	2035.70	25.90	3.10	0.119691	0.000375
30.00	2065.70	25.20	3.30	0.130952	0.000869
31.00	2096.70	20.90	3.30	0.157895	
24.00	2120.70	19.60	2.60	0.132653	0.000164

31.00	2151.70	16.70	2.30	0.137725	0.000105
17.30	2169.00	17.20	2.40	0.139535	0.135751
4.00	2173.00	18.90	12.90	0.68254	
15.40	2188.40	35.40	1.90	0.053672	0.037439
31.00	2219.40	12.60	15.30	1.214286	
30.00	2249.40	19.00	0.00	0	0.001587
28.00	2277.40	22.50	1.00	0.044444	5.97E-05
31.00	2308.40	21.60	1.00	0.046296	
30.00	2338.40	25.20	0.00	0	0.00431
12.00	2350.40	23.20	1.20	0.051724	0.000882
30.00	2380.40	24.30	1.90	0.078189	
16.00	2396.40	23.60	1.10	0.04661	0.000342
14.00	2410.40	21.40	1.10	0.051402	
30.00	2440.40	21.70	1.10	0.050691	0.000157
31.00	2471.40	21.60	1.20	0.055556	
30.00	2501.40	23.00	1.00	0.043478	0.001705
31.00	2532.40	21.80	2.10	0.09633	
31.00	2563.40	22.00	1.10	0.05	0.000313
29.00	2592.40	22.00	1.30	0.059091	
31.00	2623.40	22.00	1.10	0.05	0.005782
30.00	2653.40	17.90	4.00	0.223464	0.001455
31.00	2684.40	17.50	4.70	0.268571	
30.00	2714.40	18.20	4.60	0.252747	0.000217
31.00	2745.40	18.50	4.80	0.259459	
31.00	2776.40	18.20	4.60	0.252747	
30.00	2806.40	18.50	4.50	0.243243	
31.00	2837.40	18.70	4.20	0.224599	
30.00	2867.40	18.40	4.00	0.217391	0.000877
31.00	2898.40	18.40	4.50	0.244565	0.007162
14.00	2912.40	17.40	6.00	0.344828	0.00093
14.00	2926.40	20.40	7.30	0.357843	
16.00	2942.40	20.10	6.80	0.338308	0.083988
15.00	2957.40	10.70	17.10	1.598131	
15.00	2972.40	13.40	13.30	0.992537	
15.00	2987.40	13.50	13.30	0.985185	0.00072
31.00	3018.40	13.30	13.40	1.007519	0.025414
16.00	3034.40	9.90	14.00	1.414141	
30.00	3064.40	10.40	14.20	1.365385	0.001367
31.00	3095.40	10.30	14.50	1.407767	
30.00	3125.40	10.30	14.30	1.38835	0.001294
30.00	3155.40	10.30	14.70	1.427184	
31.00	3186.40	14.10	8.50	0.602837	
13.00	3199.40	15.80	8.60	0.544304	0.001682
15.00	3214.40	15.10	8.60	0.569536	
18.00	3232.40	16.50	8.50	0.515152	
6.00	3238.40	16.30	8.30	0.509202	
26.00	3264.40	13.50	4.10	0.303704	

14.00	3278.40	14.50	4.10	0.282759	
16.00	3294.40	13.90	3.90	0.280576	0.000875
15.00	3309.40	14.30	4.20	0.293706	
15.00	3324.40	15.90	4.30	0.27044	0.000959
14.00	3338.40	15.50	4.40	0.283871	
13.00	3351.40	15.70	4.00	0.254777	0.0131
13.00	3364.40	32.70	13.90	0.425076	
28.00	3392.40	16.90	4.40	0.260355	0.001909
31.00	3423.40	16.90	5.40	0.319527	0
15.00	3438.40	16.90	5.40	0.319527	0.000664
15.00	3453.40	17.30	5.70	0.32948	
30.00	3483.40	19.10	3.30	0.172775	
15.00	3498.40	19.50	3.30	0.169231	0.011436
16.00	3514.40	15.90	5.60	0.352201	0.001103
15.00	3529.40	16.00	5.90	0.36875	
31.00	3560.40	15.40	5.10	0.331169	0.001192
13.00	3573.40	15.00	5.20	0.346667	
14.00	3587.40	15.60	4.90	0.314103	0.000341
31.00	3618.40	15.40	5.00	0.324675	
29.00	3647.40	15.20	4.90	0.322368	
14.00	3661.40	15.40	4.90	0.318182	0.000921
14.00	3675.40	14.80	4.90	0.331081	0.00047
14.00	3689.40	15.40	5.20	0.337662	0.000177
14.00	3703.40	14.70	5.00	0.340136	0.000574
16.00	3719.40	14.60	5.10	0.349315	
14.00	3733.40	15.30	5.20	0.339869	
14.00	3747.40	15.70	5.20	0.33121	
14.00	3761.40	15.40	5.10	0.331169	
30.00	3791.40	13.90	4.50	0.323741	0.003942
31.00	3822.40	14.80	6.60	0.445946	
31.00	3853.40	14.90	4.70	0.315436	0.000639
28.00	3881.40	15.00	5.00	0.333333	
11.00	3892.40	14.90	4.90	0.328859	0.002045
11.00	3903.40	14.80	5.20	0.351351	
13.00	3916.40	15.50	5.20	0.335484	0.000328
13.00	3929.40	15.60	5.30	0.339744	
12.00	3941.40	15.70	5.30	0.33758	
31.00	3972.40	14.90	4.70	0.315436	0.003441
9.00	3981.40	15.30	5.30	0.346405	0.005602
7.00	3988.40	15.30	5.90	0.385621	
13.00	4001.40	14.90	5.00	0.33557	0.000712
13.00	4014.40	14.50	5.00	0.344828	
6.00	4020.40	15.70	5.30	0.33758	0.003558
11.00	4031.40	14.60	5.50	0.376712	
14.00	4045.40	14.80	5.20	0.351351	
13.00	4058.40	14.20	4.70	0.330986	3.74E-06
13.00	4071.40	14.50	4.80	0.331034	

13.00	4084.40	14.10	4.50	0.319149	0.003077
13.00	4097.40	14.20	5.10	0.359155	
4.00	4101.40	13.80	4.80	0.347826	0.003694
12.00	4113.40	15.30	6.00	0.392157	
14.00	4127.40	14.40	5.10	0.354167	
13.00	4140.40	14.30	5.00	0.34965	0.003249
13.00	4153.40	14.80	5.80	0.391892	
31.00	4184.40	14.40	5.30	0.368056	0.000851
28.00	4212.40	14.80	5.80	0.391892	
25.00	4237.40	15.20	5.70	0.375	
21.00	4258.40	14.30	4.30	0.300699	
27.00	4285.40	14.10	3.70	0.262411	0.000173
30.00	4315.40	14.20	3.80	0.267606	0.001556
30.00	4345.40	14.00	4.40	0.314286	
28.00	4373.40	14.50	3.70	0.255172	0.000542
30.00	4403.40	14.00	3.80	0.271429	0.001128
24.00	4427.40	13.40	4.00	0.298507	
31.00	4458.40	14.10	3.80	0.269504	
29.00	4487.40	14.20	3.70	0.260563	0.000211
14.00	4501.40	14.80	3.90	0.263514	0.00074
30.00	4531.40	14.00	4.00	0.285714	0
31.00	4562.40	14.00	4.00	0.285714	
14.00	4576.40	13.90	3.60	0.258993	0.000568
31.00	4607.40	14.10	3.90	0.276596	
31.00	4638.40	14.10	3.80	0.269504	0.114939
7.00	4645.40	2.70	2.90	1.074074	
22.00	4667.40	7.50	6.30	0.84	
14.00	4681.40	11.20	6.10	0.544643	
31.00	4712.40	9.20	4.50	0.48913	0.00256
29.00	4741.40	7.10	4.00	0.56338	
27.00	4768.40	7.50	3.80	0.506667	
31.00	4799.40	7.40	3.50	0.472973	0.007284
29.00	4828.40	7.60	5.20	0.684211	
31.00	4859.40	9.50	5.40	0.568421	0.005875
30.00	4889.40	9.40	7.00	0.744681	
31.00	4920.40	11.30	7.20	0.637168	0.005892
31.00	4951.40	11.10	9.10	0.81982	
30.00	4981.40	7.40	4.50	0.608108	0.009057
31.00	5012.40	7.20	6.40	0.888889	
30.00	5042.40	7.40	6.00	0.810811	
31.00	5073.40	7.40	5.80	0.783784	
31.00	5104.40	7.50	4.50	0.6	0.005968
24.00	5128.40	7.40	5.50	0.743243	0.001654
31.00	5159.40	7.30	5.80	0.794521	0.000154

Table 5: Production history of Well A(2)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
2.00	2.00	34.00	20.00	0.588235294	
31.00	33.00	52.50	14.20	0.27047619	3.44775E-05
30.00	63.00	52.30	14.20	0.271510516	
31.00	94.00	79.30	11.10	0.139974779	
30.00	124.00	88.30	12.00	0.13590034	0.000197806
31.00	155.00	86.60	12.30	0.142032333	
31.00	186.00	89.00	12.30	0.138202247	0.000400823
28.00	214.00	78.30	11.70	0.149425287	
31.00	245.00	77.80	10.20	0.131105398	
30.00	275.00	78.70	9.80	0.124523507	0.035040636
30.00	305.00	40.40	47.50	1.175742574	0.000623396
30.00	335.00	28.80	34.40	1.194444444	0.005163568
31.00	366.00	29.90	40.50	1.35451505	
31.00	397.00	32.60	41.00	1.257668712	0.005124757
30.00	427.00	33.30	47.00	1.411411411	0.006460401
31.00	458.00	29.10	46.90	1.611683849	
30.00	488.00	28.80	45.40	1.576388889	
31.00	519.00	31.80	47.00	1.477987421	
31.00	550.00	31.70	43.70	1.378548896	0.008814401
28.00	578.00	35.50	57.70	1.625352113	0.003150966
31.00	609.00	34.30	59.10	1.72303207	
30.00	639.00	34.20	47.00	1.374269006	
30.00	669.00	32.90	37.90	1.151975684	0.00097018
30.00	699.00	37.00	43.70	1.181081081	
31.00	730.00	36.50	38.20	1.046575342	
31.00	761.00	36.70	38.30	1.04359673	0.013587639
28.00	789.00	31.60	45.00	1.424050633	
31.00	820.00	35.50	39.90	1.123943662	0.003004121
30.00	850.00	32.70	39.70	1.214067278	0.003986937
31.00	881.00	30.80	41.20	1.337662338	
31.00	912.00	36.60	38.40	1.049180328	
29.00	941.00	36.00	35.80	0.994444444	0.000262351
31.00	972.00	38.80	38.90	1.00257732	0.002154233
30.00	1002.00	37.20	39.70	1.067204301	0.006750525
31.00	1033.00	34.00	43.40	1.276470588	
30.00	1063.00	34.10	39.20	1.149560117	0.00259769
31.00	1094.00	33.90	41.70	1.230088496	
31.00	1125.00	33.70	40.60	1.204747774	
30.00	1155.00	33.80	37.20	1.100591716	0.001813323
31.00	1186.00	33.80	39.10	1.156804734	
30.00	1216.00	33.60	38.00	1.130952381	
31.00	1247.00	33.40	37.60	1.125748503	0.003364931
31.00	1278.00	32.60	40.10	1.23006135	
28.00	1306.00	34.20	37.00	1.081871345	

31.00	1337.00	34.20	34.60	1.011695906	0.015273938
30.00	1367.00	34.90	51.30	1.46991404	
31.00	1398.00	35.20	38.60	1.096590909	0.011477709
30.00	1428.00	34.70	50.00	1.44092219	
31.00	1459.00	34.80	44.80	1.287356322	0.011083744
31.00	1490.00	33.60	54.80	1.630952381	
30.00	1520.00	34.30	37.50	1.093294461	0.016693032
31.00	1551.00	33.40	53.80	1.610778443	
30.00	1581.00	34.10	50.20	1.472140762	
31.00	1612.00	33.10	48.40	1.46223565	
31.00	1643.00	33.70	37.00	1.097922849	0.009372768
28.00	1671.00	33.30	45.30	1.36036036	0.0032863
31.00	1702.00	33.10	48.40	1.46223565	0.000859128

Table 6: Production history of Well A(3)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
31.00	31.00	29.10	14.10	0.484536	0.004306
28.00	59.00	31.40	19.00	0.605096	0.001469
31.00	90.00	31.20	20.30	0.650641	0.029968
20.00	110.00	24.00	30.00	1.25	0.011364

Table 7: Production history of Well A(4)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
5.10	5.10	58.40	0.00	0	
20.80	25.90	73.90	0.00	0	0
30.00	55.90	68.70	0.00	0	0
30.70	86.60	69.90	0.00	0	0
30.00	116.60	87.50	0.00	0	0
31.00	147.60	71.20	0.00	0	0
31.00	178.60	70.80	0.00	0	0
28.00	206.60	69.00	0.00	0	0
31.00	237.60	70.40	0.00	0	0
30.00	267.60	68.70	0.00	0	0
31.00	298.60	66.70	0.00	0	0
30.00	328.60	68.10	0.00	0	0
31.00	359.60	68.80	0.00	0	0
31.00	390.60	68.80	0.00	0	0
30.00	420.60	67.90	0.00	0	0
31.00	451.60	69.20	0.00	0	0
30.00	481.60	68.20	0.00	0	0
31.00	512.60	73.80	0.00	0	0

31.00	543.60	76.30	0.00	0	0
28.00	571.60	77.80	0.00	0	0
31.00	602.60	77.40	0.00	0	0
30.00	632.60	78.30	0.00	0	0
31.00	663.60	76.20	0.00	0	0
30.00	693.60	85.40	0.00	0	0.004943179
31.00	724.60	63.30	9.70	0.153238547	-0.00082399
31.00	755.60	60.30	7.70	0.127694859	-4.98925E-05
30.00	785.60	62.60	7.90	0.126198083	0.000275241
31.00	816.60	66.80	9.00	0.134730539	0.000110373
30.00	846.60	62.30	8.60	0.138041734	0.000184782
31.00	877.60	62.60	9.00	0.143769968	-0.001416603
31.00	908.60	69.10	6.90	0.099855282	-0.000221539
29.00	937.60	68.50	6.40	0.093430657	0.00104896
31.00	968.60	65.90	8.30	0.125948407	0.000139296
30.00	998.60	70.70	9.20	0.130127298	-0.001177751
31.00	1029.60	70.50	6.60	0.093617021	0.000803923
30.00	1059.60	67.10	7.90	0.117734724	0.001240885
31.00	1090.60	65.30	10.20	0.156202144	-0.000121391
31.00	1121.60	65.60	10.00	0.152439024	-5.27886E-05
30.00	1151.60	64.30	9.70	0.150855365	0.000178798
31.00	1182.60	63.30	9.90	0.156398104	0.001150366
30.00	1212.60	66.00	12.60	0.190909091	-0.001262044
31.00	1243.60	67.20	10.20	0.151785714	0.003901341
31.00	1274.60	62.70	17.10	0.272727273	0.000527597
28.00	1302.60	64.00	18.40	0.2875	-0.000653971
31.00	1333.60	59.50	15.90	0.267226891	0.000291756
30.00	1363.60	58.70	16.20	0.275979557	-0.008902566
31.00	1394.60	55.70	0.00	0	0.007565012
30.00	1424.60	56.40	12.80	0.226950355	-0.000176788
30.90	1455.50	60.50	13.40	0.221487603	-3.79933E-05
31.00	1486.50	58.10	12.80	0.220309811	0.000252071
30.00	1516.50	53.10	12.10	0.22787194	9.7769E-05
31.00	1547.50	57.60	13.30	0.230902778	-0.000144676
30.00	1577.50	64.00	14.50	0.2265625	0.000716191
31.00	1608.50	60.70	15.10	0.248764415	0.000512652
31.00	1639.50	59.70	15.80	0.264656616	-0.00135913
28.00	1667.50	60.90	13.80	0.226600985	0.0006428
31.00	1698.50	57.60	14.20	0.246527778	0.002585411
30.00	1728.50	57.70	18.70	0.324090121	4.94405E-05
31.00	1759.50	56.20	18.30	0.325622776	0.001235109
30.00	1789.50	56.80	20.60	0.362676056	0.003631902
31.00	1820.50	56.60	26.90	0.475265018	-0.002579841
30.90	1851.40	58.40	23.10	0.395547945	0.002168604
30.00	1881.40	49.50	22.80	0.460606061	-0.00037231
31.00	1912.40	48.10	21.60	0.449064449	0.003083779
30.00	1942.40	46.90	25.40	0.541577825	0.001267348

31.00	1973.40	43.90	25.50	0.580865604	-0.001097569
31.00	2004.40	45.90	25.10	0.546840959	0.00149216
28.00	2032.40	45.70	26.90	0.588621444	0.000585287
31.00	2063.40	47.30	28.70	0.606765328	0.001716237
30.00	2093.40	51.50	33.90	0.658252427	0.001053441
31.00	2124.40	49.50	34.20	0.690909091	0.014896206
30.00	2154.40	50.80	57.80	1.137795276	-0.013986127
31.00	2185.40	49.70	35.00	0.704225352	0.003115208
31.00	2216.40	50.20	40.20	0.800796813	-0.002855637
30.00	2246.40	50.90	36.40	0.715127701	0.002618342
31.00	2277.40	48.60	38.70	0.796296296	-0.006323572
30.00	2307.40	51.60	31.30	0.606589147	0.000907787
31.00	2338.40	50.10	31.80	0.634730539	0.000775649
30.00	2368.40	50.00	32.90	0.658	-0.002669706
29.00	2397.40	48.40	28.10	0.580578512	0.007531325
31.00	2428.40	48.40	39.40	0.814049587	0.001812382
30.00	2458.40	41.80	36.30	0.868421053	0.0003161
31.00	2489.40	42.70	37.50	0.878220141	-0.002154122
30.00	2519.40	45.60	37.10	0.813596491	0.007618276
31.00	2550.40	42.20	44.30	1.049763033	-0.000934962
31.00	2581.40	38.50	39.30	1.020779221	-0.002525974
30.00	2611.40	40.00	37.80	0.945	-0.00117284
31.00	2642.40	40.50	36.80	0.908641975	-0.001182375
30.00	2672.40	41.00	35.80	0.873170732	0.005144922
31.00	2703.40	39.80	41.10	1.032663317	0.002564791
31.00	2734.40	41.90	46.60	1.112171838	0.000732368
28.00	2762.40	40.70	46.10	1.132678133	-0.003520926
31.00	2793.40	42.50	43.50	1.023529412	-0.005780411
30.00	2823.40	42.70	36.30	0.850117096	1.9155E-05
31.00	2854.40	42.20	35.90	0.8507109	-0.000418222
30.00	2884.40	41.40	34.70	0.838164251	0.001583569
31.00	2915.40	40.80	36.20	0.887254902	0.003724835
31.00	2946.40	36.70	36.80	1.002724796	-0.001068604
30.00	2976.40	37.50	36.40	0.970666667	0.001033186
31.00	3007.40	37.10	37.20	1.002695418	-0.000449236
30.00	3037.40	37.10	36.70	0.989218329	0.001047158
31.00	3068.40	36.90	37.70	1.021680217	0.001255672
31.00	3099.40	36.30	38.50	1.060606061	0.001208514
28.00	3127.40	36.00	39.40	1.094444444	-0.000896057
31.00	3158.40	36.00	38.40	1.066666667	-0.00098438
30.00	3188.40	37.70	39.10	1.037135279	0.042386317
31.00	3219.40	22.50	52.90	2.351111111	0.017665666
30.00	3249.40	18.50	53.30	2.881081081	0.006804628
31.00	3280.40	16.30	50.40	3.09202454	0.007295396
31.00	3311.40	15.40	51.10	3.318181818	0.021328671
30.00	3341.40	14.30	56.60	3.958041958	-0.002600729
31.00	3372.40	15.50	60.10	3.877419355	0.001705069

30.00	3402.40	15.40	60.50	3.928571429	0.002503271
31.00	3433.40	16.20	64.90	4.00617284	-0.003228887
31.00	3464.40	18.10	70.70	3.906077348	0.028522166
28.00	3492.40	14.90	70.10	4.704697987	-0.005790907
31.00	3523.40	13.90	62.90	4.525179856	-0.000601233
30.00	3553.40	14.00	63.10	4.507142857	0.002495619
31.00	3584.40	14.20	65.10	4.584507042	-9.82253E-05
30.00	3614.40	14.10	64.60	4.581560284	-0.017621489
31.00	3645.40	17.00	68.60	4.035294118	-0.013846242
31.00	3676.40	16.50	59.50	3.606060606	-0.005858586
30.00	3706.40	16.50	56.60	3.43030303	0.001368524
31.00	3737.40	16.50	57.30	3.472727273	-0.024658099
30.00	3767.40	19.10	52.20	2.732984293	0.015571032
31.00	3798.40	15.30	49.20	3.215686275	0.022164242
31.00	3829.40	14.40	56.20	3.902777778	-0.030528825
29.00	3858.40	17.20	51.90	3.01744186	0.007816077
31.00	3889.40	15.40	50.20	3.25974026	0.008885851
30.00	3919.40	15.20	53.60	3.526315789	0.009640614
31.00	3950.40	14.30	54.70	3.825174825	0.008684649
30.00	3980.40	14.00	57.20	4.085714286	-0.000230415
31.00	4011.40	14.00	57.10	4.078571429	0.050066426
31.00	4042.40	11.10	62.50	5.630630631	0.078978979
30.00	4072.40	8.10	64.80	8	-0.036115007
31.00	4103.40	9.20	63.30	6.880434783	0.036944309
30.00	4133.40	8.90	71.10	7.988764045	-0.052611803
31.00	4164.40	10.90	69.30	6.357798165	0.05488341
24.00	4188.40	4.00	30.70	7.675	0.516346154
26.00	4214.40	1.00	21.10	21.1	-0.508333333
30.00	4244.40	4.00	23.40	5.85	0.25483871
31.00	4275.40	2.00	27.50	13.75	-0.016129032
31.00	4306.40	2.00	26.50	13.25	-0.125574713
30.00	4336.40	2.90	27.50	9.482758621	0.024956504
31.00	4367.40	3.90	40.00	10.25641026	-0.208547009
30.00	4397.40	9.00	36.00	4	0.244003309
31.00	4428.40	3.90	45.10	11.56410256	-0.010132341
31.00	4459.40	4.00	45.00	11.25	-0.038630229
26.00	4485.40	5.70	58.40	10.24561404	-0.015038783
31.00	4516.40	6.80	66.50	9.779411765	-0.024189676
21.00	4537.40	7.00	64.90	9.271428571	-0.158151562
30.00	4567.40	9.30	42.10	4.52688172	0.000991129

Table 8: Production history of Well A(5)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
24.00	24.00	60.90	0.00	0.00	
31.00	55.00	67.00	0.00	0.00	0.0000000000
31.00	86.00	66.40	0.00	0.00	0.0000000000

28.00	114.00	66.50	0.00	0.00	0.0000000000
31.00	145.00	68.60	0.00	0.00	0.0000000000
30.00	175.00	69.20	0.00	0.00	0.0000000000
31.00	206.00	71.80	0.00	0.00	0.0000000000
30.00	236.00	73.50	0.00	0.00	0.0000000000
31.00	267.00	73.00	0.00	0.00	0.0007837637
31.00	298.00	78.20	1.90	0.02	0.0000766356
30.00	328.00	75.20	2.00	0.03	0.0000381301
31.00	359.00	72.00	2.00	0.03	- 0.0005035361
29.00	388.00	75.90	1.00	0.01	0.0005817547
30.00	418.00	65.30	2.00	0.03	0.0003815955
30.00	448.00	71.30	3.00	0.04	- 0.0000384581
29.00	477.00	70.80	2.90	0.04	- 0.0000871573
31.00	508.00	75.80	2.90	0.04	0.0006598859
30.00	538.00	68.90	4.00	0.06	- 0.0000434514
31.00	569.00	72.30	4.10	0.06	- 0.0000139100
28.00	597.00	72.80	4.10	0.06	0.0001815555
31.00	628.00	67.80	4.20	0.06	- 0.0000646897
31.00	659.00	68.40	4.10	0.06	- 0.0000572452
30.00	689.00	68.70	4.00	0.06	0.0000137698
31.00	720.00	68.20	4.00	0.06	- 0.0008503272
30.00	750.00	69.40	2.30	0.03	0.0010430639
31.00	781.00	67.20	4.40	0.07	- 0.0002743444
31.00	812.00	66.70	3.80	0.06	0.0000599826
28.00	840.00	68.20	4.00	0.06	0.0001085315
31.00	871.00	64.50	4.00	0.06	0.0063130542
30.00	901.00	53.30	13.40	0.25	0.0002619678
31.00	932.00	55.10	14.30	0.26	0.0008563087
30.00	962.00	57.50	16.40	0.29	- 0.0006911061
31.00	993.00	58.00	15.30	0.26	0.0000178943
31.00	1024.00	57.50	15.20	0.26	0.0002470204
30.00	1054.00	56.30	15.30	0.27	0.0008310395
31.00	1085.00	48.40	14.40	0.30	0.0007588012
30.00	1115.00	56.20	18.00	0.32	- 0.0019013447
31.00	1146.00	55.10	14.40	0.26	0.0001119936
31.00	1177.00	54.00	14.30	0.26	- 0.0008689423
28.00	1205.00	57.80	13.90	0.24	0.0021943938
31.00	1236.00	56.40	17.40	0.31	0.0001738284
30.00	1266.00	56.10	17.60	0.31	-

					0.0004778209
31.00	1297.00	55.20	16.50	0.30	-0.0020001731
30.00	1327.00	58.60	14.00	0.24	0.0046360296
31.00	1358.00	54.10	20.70	0.38	-0.0003285578
31.00	1389.00	53.70	20.00	0.37	0.0027425834
30.00	1419.00	53.00	24.10	0.45	0.0013010492
31.00	1450.00	50.50	25.00	0.50	-0.0079123441
30.00	1480.00	58.60	15.10	0.26	0.0009200594
31.00	1511.00	58.70	16.80	0.29	-0.0004246284
31.00	1542.00	58.60	16.00	0.27	0.0005120669
28.00	1570.00	60.20	17.30	0.29	0.0004178909
31.00	1601.00	60.60	18.20	0.30	-0.0019484259
30.00	1631.00	55.40	13.40	0.24	-0.0016951133
31.00	1662.00	58.10	11.00	0.19	0.0015762037
30.00	1692.00	57.90	13.70	0.24	-0.0013054111
31.00	1723.00	57.10	11.20	0.20	0.0000120848
31.00	1754.00	57.50	11.30	0.20	0.0012412325
29.00	1783.00	57.20	13.30	0.23	-0.0014354037
31.00	1814.00	60.10	11.30	0.19	0.0003993344
30.00	1844.00	57.00	11.40	0.20	0.0006194483
31.00	1875.00	55.20	12.10	0.22	-0.0007827803
31.00	1906.00	39.50	7.70	0.19	-0.0003105883
29.00	1935.00	39.80	7.40	0.19	0.0033401302
31.00	1966.00	45.60	13.20	0.29	0.0006248498
30.00	1996.00	43.80	13.50	0.31	-0.0000617055
31.00	2027.00	44.40	13.60	0.31	-0.0007720080
30.00	2057.00	44.50	12.60	0.28	0.0085341004
31.00	2088.00	28.30	15.50	0.55	0.0030776245
31.00	2119.00	28.30	18.20	0.64	0.0030243588
30.00	2149.00	26.30	19.30	0.73	0.0021087837
31.00	2180.00	25.40	20.30	0.80	-0.0014807775
30.00	2210.00	26.10	19.70	0.75	0.0028236897
31.00	2241.00	24.10	20.30	0.84	0.0021670520
31.00	2272.00	22.10	20.10	0.91	0.0039323422
28.00	2300.00	20.40	20.80	1.02	-0.0077544214
31.00	2331.00	23.10	18.00	0.78	0.0088559060
30.00	2361.00	24.50	25.60	1.04	-0.0075475351

31.00	2392.00	23.80	19.30	0.81	0.0172954288
30.00	2422.00	18.80	25.00	1.33	-0.0025287286
31.00	2453.00	17.90	22.40	1.25	0.0053456662
31.00	2484.00	18.70	26.50	1.42	-0.0146613191
30.00	2514.00	17.60	17.20	0.98	0.0327920785
31.00	2545.00	16.20	32.30	1.99	-0.0080271704
30.00	2575.00	16.60	29.10	1.75	-0.0019432569
31.00	2606.00	16.60	28.10	1.69	-0.0119787907
31.00	2637.00	19.60	25.90	1.32	0.0111640017
28.00	2665.00	19.40	31.70	1.63	-0.0049571379
31.00	2696.00	22.90	33.90	1.48	-0.0134254379
30.00	2726.00	23.20	25.00	1.08	0.0028735632
31.00	2757.00	23.40	27.30	1.17	-0.0007097406
30.00	2787.00	22.70	26.00	1.15	0.0100370093
31.00	2818.00	18.40	26.80	1.46	0.0115300564
31.00	2849.00	12.90	23.40	1.81	-0.0031174460
30.00	2879.00	9.30	16.00	1.72	0.0187304891
31.00	2910.00	9.30	21.40	2.30	-0.0173529155
30.00	2940.00	8.20	14.60	1.78	0.0080093282
31.00	2971.00	13.90	28.20	2.03	0.0638199118
31.00	3002.00	13.90	55.70	4.01	-0.0572970195
28.00	3030.00	13.90	33.40	2.40	-0.0091469681
5.00	3035.00	14.00	33.00	2.36	0.0007766533

Table 9: Production history of Well A(6)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
15	15.00	91.5	2.1	0.02295082	
31	46.00	95.7	1	0.010449321	0.000251576
31	77.00	109.6	2	0.018248175	0.000349404
30	107.00	107.9	3.1	0.028730306	0.000113
31	138.00	130.3	4.2	0.032233308	6.50161E-06
30	168.00	132.6	4.3	0.032428356	
31	199.00	131.9	4.2	0.031842305	0.000108155
31	230.00	130.7	4.6	0.035195103	0.000894163
28	258.00	129.5	7.8	0.06023166	1.91613E-06
31	289.00	144.3	8.7	0.06029106	

30	319.00	148.4	7.6	0.051212938	0.001139533
31	350.00	145.6	12.6	0.086538462	
30	380.00	147.1	12.2	0.082936778	
31	411.00	150.1	8.6	0.057295137	
31	442.00	156.4	5.8	0.037084399	
30	472.00	173.1	4	0.02310803	
31	503.00	181	4.1	0.022651934	0.000629872
30	533.00	175.7	7.3	0.041548093	
31	564.00	182.6	6.7	0.036692223	2.97407E-05
31	595.00	186.1	7	0.037614186	
29	624.00	183	5.9	0.032240437	0.000277689
31	655.00	188.5	7.7	0.040848806	
30	685.00	191.6	6.1	0.031837161	1.24959E-05
31	716.00	192.4	6.2	0.032224532	
30	746.00	189.5	6.1	0.032189974	2.26217E-05
31	777.00	188.5	6.2	0.032891247	
31	808.00	190	5.1	0.026842105	0.000169279
30	838.00	191.1	6.1	0.03192046	0.000402408
31	869.00	180.2	8	0.044395117	
30	899.00	184.3	6.8	0.036896365	
31	930.00	183.8	3.3	0.017954298	0.000252953
31	961.00	182.2	4.7	0.025795829	5.77304E-05
28	989.00	182.4	5	0.027412281	
31	1020.00	182.4	4	0.021929825	0.00021982
30	1050.00	182.3	5.2	0.02852441	
30	1080.00	183.9	4.1	0.022294725	0.000179752
30	1110.00	184.2	5.1	0.027687296	
31	1141.00	189.1	5.1	0.026969857	
31	1172.00	137.7	21.8	0.158315178	0.006396337
20	1192.00	108.3	31	0.286241921	
16	1208.00	114.3	30.3	0.265091864	
27	1235.00	107.1	44.7	0.417366947	0.003678672
31	1266.00	100.3	53.3	0.531405783	
31	1297.00	99	52.2	0.527272727	
28	1325.00	90.9	53.5	0.588558856	
31	1356.00	93.4	52.2	0.55888651	
30	1386.00	93.2	49.7	0.533261803	0.019748153
31	1417.00	66	75.6	1.145454545	
30	1447.00	56.7	69.8	1.231040564	0.006418701
31	1478.00	49.3	70.5	1.430020284	
31	1509.00	51.8	65.9	1.272200772	0.03752528
30	1539.00	39.2	94	2.397959184	
31	1570.00	11.6	44.8	3.862068966	
30	1600.00	22.1	96.8	4.380090498	
24	1624.00	8.5	18	2.117647059	0.033556377
31	1655.00	1.9	6	3.157894737	0.209192336
31	1686.00	2.8	27	9.642857143	
30	1716.00	3.7	31.9	8.621621622	

31	1747.00	3.9	26.4	6.769230769	
31	1778.00	0	7.2		
30	1808.00	0	6.7		

Table 10: Production history of Well A(7)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
5.10	5.10	48.70	13.70	0.281314168	
20.80	25.90	51.60	0.00	0	0
30.00	55.90	52.70	0.00	0	0
30.70	86.60	52.30	0.00	0	0
30.00	116.60	52.70	0.00	0	0.000811131
31.00	147.60	51.70	1.30	0.025145068	-0.000124789
31.00	178.60	51.70	1.10	0.021276596	3.24734E-06
28.00	206.60	46.80	1.00	0.021367521	0.000159622
31.00	237.60	45.60	1.20	0.026315789	-3.68568E-05
30.00	267.60	47.60	1.20	0.025210084	-1.34418E-05
31.00	298.60	48.40	1.20	0.024793388	-1.70401E-06
30.00	328.60	48.50	1.20	0.024742268	-7.83837E-05
31.00	359.60	49.30	1.10	0.022312373	-7.22645E-06
31.00	390.60	49.80	1.10	0.022088353	-5.87717E-05
30.00	420.60	49.20	1.00	0.020325203	8.35956E-05
31.00	451.60	48.00	1.10	0.022916667	8.89896E-05
30.00	481.60	46.90	1.20	0.025586354	1.7636E-06
31.00	512.60	46.80	1.20	0.025641026	-3.227E-05
31.00	543.60	48.70	1.20	0.024640657	-9.58775E-05
28.00	571.60	50.10	1.10	0.021956088	-4.1772E-05
31.00	602.60	48.40	1.00	0.020661157	0.001477612
30.00	632.60	47.70	3.10	0.064989518	-0.000652045
31.00	663.60	46.90	2.10	0.044776119	-0.000129211
30.00	693.60	48.90	2.00	0.040899796	-2.90257E-05
31.00	724.60	50.00	2.00	0.04	7.82014E-05
31.00	755.60	49.50	2.10	0.042424242	-0.000217253
30.00	785.60	55.70	2.00	0.035906643	2.18943E-05
31.00	816.60	57.40	2.10	0.036585366	0.002028037
30.00	846.60	54.40	5.30	0.097426471	8.30171E-05

31.00	877.60	44.00	4.40	0.1	7.68049E-05
31.00	908.60	42.00	4.30	0.102380952	-0.000146556
29.00	937.60	42.80	4.20	0.098130841	-0.000154758
31.00	968.60	45.00	4.20	0.093333333	0.001126177
30.00	998.60	47.20	6.00	0.127118644	0.000782816
31.00	1029.60	46.90	7.10	0.151385928	0.001000666
30.00	1059.60	44.10	8.00	0.181405896	0.000789563
31.00	1090.60	40.80	8.40	0.205882353	0.00094407
31.00	1121.60	40.40	9.50	0.235148515	0.000670488
30.00	1151.60	38.00	9.70	0.255263158	-0.0003583
31.00	1182.60	38.50	9.40	0.244155844	0.001809116
30.00	1212.60	38.20	11.40	0.298429319	-0.00017914
31.00	1243.60	37.90	11.10	0.292875989	0.000563511
31.00	1274.60	34.80	10.80	0.310344828	-0.000866271
28.00	1302.60	38.10	10.90	0.286089239	0.000347928
31.00	1333.60	38.40	11.40	0.296875	0.003335719
30.00	1363.60	39.30	15.60	0.396946565	0.005743659
31.00	1394.60	28.00	16.10	0.575	-0.004481982
30.00	1424.60	37.00	16.30	0.440540541	0.003363555
30.90	1455.50	37.10	20.20	0.544474394	0.001701543
31.00	1486.50	36.00	21.50	0.597222222	-0.005334982
30.00	1516.50	38.20	16.70	0.437172775	-0.003911891
31.00	1547.50	45.90	14.50	0.315904139	-0.00148942
30.00	1577.50	48.30	13.10	0.271221532	0.012076867
31.00	1608.50	36.40	23.50	0.645604396	7.87193E-05
31.00	1639.50	35.80	23.20	0.648044693	0.001201623
28.00	1667.50	35.50	24.20	0.681690141	0.002996011
31.00	1698.50	34.60	26.80	0.774566474	-0.000892196
30.00	1728.50	34.10	25.50	0.747800587	-0.001748622
31.00	1759.50	35.90	24.90	0.693593315	-0.000467843
30.00	1789.50	36.20	24.60	0.679558011	0.006214402
31.00	1820.50	31.30	27.30	0.872204473	0.003711352
30.90	1851.40	30.50	30.10	0.986885246	0.005150963
30.00	1881.40	29.70	33.90	1.141414141	-0.000856428
31.00	1912.40	29.60	33.00	1.114864865	-0.005612552
30.00	1942.40	29.90	28.30	0.946488294	0.001940523
31.00	1973.40	30.10	30.30	1.006644518	-0.008302367
31.00	2004.40	34.30	25.70	0.749271137	-

					0.008043589
28.00	2032.40	39.50	20.70	0.524050633	0.015781884
31.00	2063.40	30.10	30.50	1.013289037	0.000107087
30.00	2093.40	30.30	30.80	1.01650165	5.32311E-06
31.00	2124.40	30.00	30.50	1.016666667	-0.012693744
30.00	2154.40	35.70	22.70	0.635854342	0.003587241
31.00	2185.40	34.00	25.40	0.747058824	0.006238066
31.00	2216.40	31.90	30.00	0.940438871	-0.002272158
30.00	2246.40	32.10	28.00	0.872274143	-0.000644079
31.00	2277.40	32.50	27.70	0.852307692	-0.000533272
30.00	2307.40	33.60	28.10	0.836309524	-0.002754199
31.00	2338.40	26.90	20.20	0.750929368	-0.011358324
30.00	2368.40	33.40	13.70	0.410179641	0.00884438
29.00	2397.40	27.60	18.40	0.666666667	-0.003387833
31.00	2428.40	36.50	20.50	0.561643836	0.001986986
30.00	2458.40	36.70	22.80	0.621253406	0.001464944
31.00	2489.40	34.50	23.00	0.666666667	0.002706956
30.00	2519.40	35.30	26.40	0.747875354	-0.002559732
31.00	2550.40	35.90	24.00	0.668523677	-0.00054317
31.00	2581.40	35.60	23.20	0.651685393	0.002340824
30.00	2611.40	35.60	25.70	0.721910112	-0.002706106
31.00	2642.40	38.40	24.50	0.638020833	0.008583385
30.00	2672.40	33.50	30.00	0.895522388	-0.010762619
31.00	2703.40	40.40	22.70	0.561881188	-0.003438601
31.00	2734.40	36.90	16.80	0.455284553	-0.002574373
28.00	2762.40	38.10	14.60	0.3832021	0.002154771
31.00	2793.40	38.00	17.10	0.45	-0.001666667
30.00	2823.40	37.50	15.00	0.4	-6.84521E-05
31.00	2854.40	37.70	15.00	0.397877984	0.002559623
30.00	2884.40	37.50	17.80	0.474666667	-0.002948966
31.00	2915.40	39.40	15.10	0.383248731	0.010724849
31.00	2946.40	29.90	21.40	0.715719064	0.003900705
30.00	2976.40	28.10	23.40	0.832740214	-0.011338394
31.00	3007.40	32.00	15.40	0.48125	0.004041149
30.00	3037.40	32.20	19.40	0.602484472	0.000310863

31.00	3068.40	33.00	20.20	0.612121212	-0.006008184
31.00	3099.40	31.70	13.50	0.425867508	0.008043673
28.00	3127.40	32.10	20.90	0.651090343	-0.001768292
31.00	3158.40	32.20	19.20	0.596273292	-0.009774766
30.00	3188.40	33.00	10.00	0.303030303	0.015203419
31.00	3219.40	22.60	17.50	0.774336283	-0.002548798
30.00	3249.40	23.50	16.40	0.69787234	-0.011759323
31.00	3280.40	37.50	12.50	0.333333333	-0.000288276
31.00	3311.40	37.30	12.10	0.324396783	0.003124396
30.00	3341.40	34.20	14.30	0.418128655	-0.000503643
31.00	3372.40	31.80	12.80	0.402515723	0.010563625
30.00	3402.40	27.80	20.00	0.71942446	-0.00435371
31.00	3433.40	29.60	17.30	0.584459459	0.00933099
31.00	3464.40	29.30	25.60	0.873720137	-0.004085647
28.00	3492.40	29.50	22.40	0.759322034	0.001824225
31.00	3523.40	31.50	25.70	0.815873016	-0.003580872
30.00	3553.40	36.70	26.00	0.708446866	0.00278551
31.00	3584.40	34.60	27.50	0.794797688	-0.007313769
30.00	3614.40	32.50	18.70	0.575384615	0.008971567
31.00	3645.40	31.40	26.80	0.853503185	-0.006833436
31.00	3676.40	36.00	23.10	0.641666667	0.007229532
30.00	3706.40	30.40	26.10	0.858552632	-0.009389289
31.00	3737.40	32.60	18.50	0.567484663	-0.004003875
30.00	3767.40	30.40	13.60	0.447368421	0.021950036
31.00	3798.40	26.60	30.00	1.127819549	-0.011638531
31.00	3829.40	27.90	21.40	0.76702509	0.002239384
29.00	3858.40	24.40	20.30	0.831967213	-0.000454768
31.00	3889.40	29.10	23.80	0.817869416	-0.008309933
30.00	3919.40	35.00	19.90	0.568571429	0.00352886
31.00	3950.40	29.50	20.00	0.677966102	0.008814024
30.00	3980.40	24.30	22.90	0.942386831	0.011299874
31.00	4011.40	20.50	26.50	1.292682927	-0.002650213
31.00	4042.40	24.70	29.90	1.210526316	-0.016997584

30.00	4072.40	33.40	23.40	0.700598802	0.004281759
31.00	4103.40	30.60	25.50	0.833333333	0.006453423
30.00	4133.40	29.70	30.50	1.026936027	0.013684734
31.00	4164.40	21.50	31.20	1.451162791	-0.018241036
24.00	4188.40	29.90	30.30	1.013377926	0.000241949

Table 11: Production history of Well A(8)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
5.10	5.10	58.40	0.00	0	
20.80	25.90	73.90	0.00	0	0
30.00	55.90	68.70	0.00	0	0
30.70	86.60	69.90	0.00	0	0
30.00	116.60	87.50	0.00	0	0
31.00	147.60	71.20	0.00	0	0
31.00	178.60	70.80	0.00	0	0
28.00	206.60	69.00	0.00	0	0
31.00	237.60	70.40	0.00	0	0
30.00	267.60	68.70	0.00	0	0
31.00	298.60	66.70	0.00	0	0
30.00	328.60	68.10	0.00	0	0
31.00	359.60	68.80	0.00	0	0
31.00	390.60	68.80	0.00	0	0
30.00	420.60	67.90	0.00	0	0
31.00	451.60	69.20	0.00	0	0
30.00	481.60	68.20	0.00	0	0
31.00	512.60	73.80	0.00	0	0
31.00	543.60	76.30	0.00	0	0
28.00	571.60	77.80	0.00	0	0
31.00	602.60	77.40	0.00	0	0
30.00	632.60	78.30	0.00	0	0
31.00	663.60	76.20	0.00	0	0
30.00	693.60	85.40	0.00	0	0.004943179
31.00	724.60	63.30	9.70	0.153238547	-0.00082399
31.00	755.60	60.30	7.70	0.127694859	-4.98925E-05
30.00	785.60	62.60	7.90	0.126198083	0.000275241
31.00	816.60	66.80	9.00	0.134730539	0.000110373
30.00	846.60	62.30	8.60	0.138041734	0.000184782
31.00	877.60	62.60	9.00	0.143769968	-0.001416603
31.00	908.60	69.10	6.90	0.099855282	-0.000221539
29.00	937.60	68.50	6.40	0.093430657	0.00104896
31.00	968.60	65.90	8.30	0.125948407	0.000139296
30.00	998.60	70.70	9.20	0.130127298	-0.001177751

31.00	1029.60	70.50	6.60	0.093617021	0.000803923
30.00	1059.60	67.10	7.90	0.117734724	0.001240885
31.00	1090.60	65.30	10.20	0.156202144	-0.000121391
31.00	1121.60	65.60	10.00	0.152439024	-5.27886E-05
30.00	1151.60	64.30	9.70	0.150855365	0.000178798
31.00	1182.60	63.30	9.90	0.156398104	0.001150366
30.00	1212.60	66.00	12.60	0.190909091	-0.001262044
31.00	1243.60	67.20	10.20	0.151785714	0.003901341
31.00	1274.60	62.70	17.10	0.272727273	0.000527597
28.00	1302.60	64.00	18.40	0.2875	-0.000653971
31.00	1333.60	59.50	15.90	0.267226891	0.000291756
30.00	1363.60	58.70	16.20	0.275979557	-0.008902566
31.00	1394.60	55.70	0.00	0	0.007565012
30.00	1424.60	56.40	12.80	0.226950355	-0.000176788
30.90	1455.50	60.50	13.40	0.221487603	-3.79933E-05
31.00	1486.50	58.10	12.80	0.220309811	0.000252071
30.00	1516.50	53.10	12.10	0.22787194	9.7769E-05
31.00	1547.50	57.60	13.30	0.230902778	-0.000144676
30.00	1577.50	64.00	14.50	0.2265625	0.000716191
31.00	1608.50	60.70	15.10	0.248764415	0.000512652
31.00	1639.50	59.70	15.80	0.264656616	-0.00135913
28.00	1667.50	60.90	13.80	0.226600985	0.0006428
31.00	1698.50	57.60	14.20	0.246527778	0.002585411
30.00	1728.50	57.70	18.70	0.324090121	4.94405E-05
31.00	1759.50	56.20	18.30	0.325622776	0.001235109
30.00	1789.50	56.80	20.60	0.362676056	0.003631902
31.00	1820.50	56.60	26.90	0.475265018	-0.002579841
30.90	1851.40	58.40	23.10	0.395547945	0.002168604
30.00	1881.40	49.50	22.80	0.460606061	-0.00037231
31.00	1912.40	48.10	21.60	0.449064449	0.003083779
30.00	1942.40	46.90	25.40	0.541577825	0.001267348
31.00	1973.40	43.90	25.50	0.580865604	-0.001097569
31.00	2004.40	45.90	25.10	0.546840959	0.00149216
28.00	2032.40	45.70	26.90	0.588621444	0.000585287
31.00	2063.40	47.30	28.70	0.606765328	0.001716237
30.00	2093.40	51.50	33.90	0.658252427	0.001053441
31.00	2124.40	49.50	34.20	0.690909091	0.014896206
30.00	2154.40	50.80	57.80	1.137795276	-0.013986127

31.00	2185.40	49.70	35.00	0.704225352	0.003115208
31.00	2216.40	50.20	40.20	0.800796813	-0.002855637
30.00	2246.40	50.90	36.40	0.715127701	0.002618342
31.00	2277.40	48.60	38.70	0.796296296	-0.006323572
30.00	2307.40	51.60	31.30	0.606589147	0.000907787
31.00	2338.40	50.10	31.80	0.634730539	0.000775649
30.00	2368.40	50.00	32.90	0.658	-0.002669706
29.00	2397.40	48.40	28.10	0.580578512	0.007531325
31.00	2428.40	48.40	39.40	0.814049587	0.001812382
30.00	2458.40	41.80	36.30	0.868421053	0.0003161
31.00	2489.40	42.70	37.50	0.878220141	-0.002154122
30.00	2519.40	45.60	37.10	0.813596491	0.007618276
31.00	2550.40	42.20	44.30	1.049763033	-0.000934962
31.00	2581.40	38.50	39.30	1.020779221	-0.002525974
30.00	2611.40	40.00	37.80	0.945	-0.00117284
31.00	2642.40	40.50	36.80	0.908641975	-0.001182375
30.00	2672.40	41.00	35.80	0.873170732	0.005144922
31.00	2703.40	39.80	41.10	1.032663317	0.002564791
31.00	2734.40	41.90	46.60	1.112171838	0.000732368
28.00	2762.40	40.70	46.10	1.132678133	-0.003520926
31.00	2793.40	42.50	43.50	1.023529412	-0.005780411
30.00	2823.40	42.70	36.30	0.850117096	1.9155E-05
31.00	2854.40	42.20	35.90	0.8507109	-0.000418222
30.00	2884.40	41.40	34.70	0.838164251	0.001583569
31.00	2915.40	40.80	36.20	0.887254902	0.003724835
31.00	2946.40	36.70	36.80	1.002724796	-0.001068604
30.00	2976.40	37.50	36.40	0.970666667	0.001033186
31.00	3007.40	37.10	37.20	1.002695418	-0.000449236
30.00	3037.40	37.10	36.70	0.989218329	0.001047158
31.00	3068.40	36.90	37.70	1.021680217	0.001255672
31.00	3099.40	36.30	38.50	1.060606061	0.001208514
28.00	3127.40	36.00	39.40	1.094444444	-0.000896057
31.00	3158.40	36.00	38.40	1.066666667	-0.00098438
30.00	3188.40	37.70	39.10	1.037135279	0.042386317
31.00	3219.40	22.50	52.90	2.351111111	0.017665666
30.00	3249.40	18.50	53.30	2.881081081	0.006804628
31.00	3280.40	16.30	50.40	3.09202454	0.007295396

31.00	3311.40	15.40	51.10	3.318181818	0.021328671
30.00	3341.40	14.30	56.60	3.958041958	-0.002600729
31.00	3372.40	15.50	60.10	3.877419355	0.001705069
30.00	3402.40	15.40	60.50	3.928571429	0.002503271
31.00	3433.40	16.20	64.90	4.00617284	-0.003228887
31.00	3464.40	18.10	70.70	3.906077348	0.028522166
28.00	3492.40	14.90	70.10	4.704697987	-0.005790907
31.00	3523.40	13.90	62.90	4.525179856	-0.000601233
30.00	3553.40	14.00	63.10	4.507142857	0.002495619
31.00	3584.40	14.20	65.10	4.584507042	-9.82253E-05
30.00	3614.40	14.10	64.60	4.581560284	-0.017621489
31.00	3645.40	17.00	68.60	4.035294118	-0.013846242
31.00	3676.40	16.50	59.50	3.606060606	-0.005858586
30.00	3706.40	16.50	56.60	3.43030303	0.001368524
31.00	3737.40	16.50	57.30	3.472727273	-0.024658099
30.00	3767.40	19.10	52.20	2.732984293	0.015571032
31.00	3798.40	15.30	49.20	3.215686275	0.022164242
31.00	3829.40	14.40	56.20	3.902777778	-0.030528825
29.00	3858.40	17.20	51.90	3.01744186	0.007816077
31.00	3889.40	15.40	50.20	3.25974026	0.008885851
30.00	3919.40	15.20	53.60	3.526315789	0.009640614
31.00	3950.40	14.30	54.70	3.825174825	0.008684649
30.00	3980.40	14.00	57.20	4.085714286	-0.000230415
31.00	4011.40	14.00	57.10	4.078571429	0.050066426
31.00	4042.40	11.10	62.50	5.630630631	0.078978979
30.00	4072.40	8.10	64.80	8	-0.036115007
31.00	4103.40	9.20	63.30	6.880434783	0.036944309
30.00	4133.40	8.90	71.10	7.988764045	-0.052611803
31.00	4164.40	10.90	69.30	6.357798165	0.05488341
24.00	4188.40	4.00	30.70	7.675	0.4475
30.00	4218.40	1.00	21.10	21.1	-0.508333333
30.00	4248.40	4.00	23.40	5.85	0.25483871
31.00	4279.40	2.00	27.50	13.75	-0.016666667
0.00	4309.40	2.00	26.50	13.25	-0.121523915
31.00	4340.40	2.90	27.50	9.482758621	0.025788388

30.00	4370.40	3.90	40.00	10.25641026	-0.201819686
31.00	4401.40	9.00	36.00	4	0.252136752
30.00	4431.40	3.90	45.10	11.56410256	-0.010132341
31.00	4462.40	4.00	45.00	11.25	-0.033479532
30.00	4492.40	5.70	58.40	10.24561404	-0.015038783
31.00	4523.40	6.80	66.50	9.779411765	-0.016932773
30.00	4553.40	7.00	64.90	9.271428571	0.002036155

Table 12: Production history of Well A(9)

Production Days	Cumulative Days	Oil Rate (KLPD)	Water Rate (KLPD)	WOR	WOR'
28	28.00	60.10	0.90	0.014975042	
31	59.00	48.90	1.50	0.030674847	-0.000475766
29	88.00	47.40	0.80	0.016877637	0.000154258
30	118.00	37.20	0.80	0.021505376	9.06688E-05
31	149.00	32.90	0.80	0.024316109	-5.06638E-06
29	178.00	33.10	0.80	0.024169184	-1.83988E-05
31	209.00	33.90	0.80	0.02359882	0.000136095
30	239.00	28.90	0.80	0.027681661	-1.21905E-05
31	270.00	29.30	0.80	0.027303754	-0.000116474
30	300.00	29.40	0.70	0.023809524	0.000115733
31	331.00	29.20	0.80	0.02739726	-0.000883783
31	362.00	30.20	0.00	0	0
30	392.00	30.10	0.00	0	0.000981234
31	423.00	26.30	0.80	0.030418251	0.000901767
30	453.00	26.10	1.50	0.057471264	0.003049314
31	484.00	25.00	3.80	0.152	-0.004903226
31	515.00	23.80	0.00	0	0.007703081
28	543.00	20.40	4.40	0.215686275	-0.000542666
31	574.00	17.60	3.50	0.198863636	0.001912879
30	604.00	16.00	4.10	0.25625	-0.001687182
31	635.00	15.20	3.10	0.203947368	0.00256505
30	665.00	17.80	5.00	0.280898876	-0.000951685
31	696.00	17.90	4.50	0.251396648	0.006294975
31	727.00	15.90	7.10	0.446540881	-0.003914232

30	757.00	15.80	5.20	0.329113924	0.010300612
30	787.00	25.70	16.40	0.638132296	0.004697916
30	817.00	25.80	20.10	0.779069767	-0.001646332
31	848.00	23.90	17.40	0.728033473	-0.005216353
31	879.00	19.60	11.10	0.566326531	-0.004765218
28	907.00	23.10	10.00	0.432900433	-0.001668139
31	938.00	20.20	7.70	0.381188119	0.002641451
30	968.00	13.90	6.40	0.460431655	0.017204067
29	997.00	12.30	11.80	0.959349593	0.001355014
30	1027.00	8.20	8.20	1	0.030498534
31	1058.00	5.50	10.70	1.945454545	0.00263137
31	1089.00	3.70	7.50	2.027027027	-0.022329472
30	1119.00	5.60	7.60	1.357142857	0.014976959
31	1150.00	5.60	10.20	1.821428571	0.087433862
30	1180.00	1.80	8.00	4.444444444	-0.059498208
31	1211.00	6.50	16.90	2.6	-0.016873449
31	1242.00	6.50	13.50	2.076923077	0.012696763
28	1270.00	7.40	18.00	2.432432432	-0.038527006
31	1301.00	16.80	20.80	1.238095238	0.09001221
30	1331.00	6.50	25.60	3.938461538	-0.020302278
31	1362.00	5.50	18.20	3.309090909	0.027285622
30	1392.00	4.70	19.40	4.127659574	-0.033932323
31	1423.00	6.60	20.30	3.075757576	0.026358051
31	1454.00	2.80	10.90	3.892857143	0.003571429
30	1484.00	2.80	11.20	4	0.016129032
31	1515.00	3.80	17.10	4.5	0.037037037
30	1545.00	1.80	10.10	5.611111111	-0.017921147
31	1576.00	1.80	9.10	5.055555556	-0.125448029
31	1607.00	1.80	2.10	1.166666667	-0.001915709
29	1636.00	1.80	2.00	1.111111111	0.035842294
31	1667.00	0.90	2.00	2.222222222	-0.007407407
30	1697.00	0.90	1.80	2	0.003225806
31	1728.00	1.00	2.10	2.1	0.001215278

Table 13: Production history of Well A(10)

7.2 Excessive Wax Deposition

Field X-1 with intermediate (G-I) reservoirs and the deeper (M-T) reservoirs have shown high wax precipitation in wells completed in these reservoirs. From lab testing, the G-I reservoirs wax percentage ranges from 1.7% - 19%, and the (M-T) reservoirs range from 12.6-21%. Severity for the intermediate reservoirs may decrease as the water cut is expected to increase. The deeper reservoirs are likely to produce with increased GOR.

Generally the wax in the well bore occurs at depths between 300-600m with a flowing temperature between 30-37 ^{0}C. This coincides with the WAT range determined from laboratory analysis. Shutting in of the wells increases the severity of the problem shifting the wax precipitation further downhole.

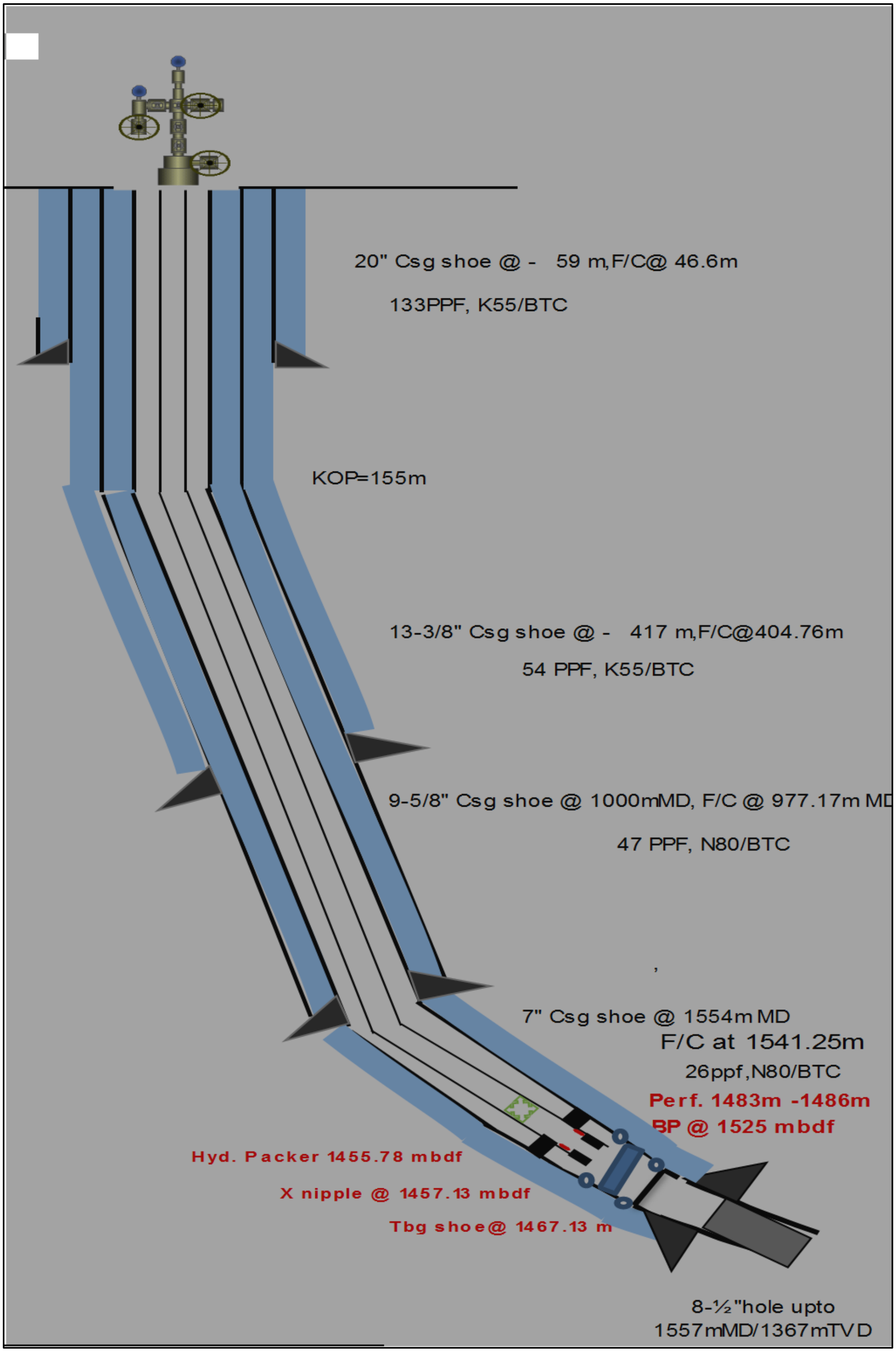


Figure 26: Well B(1) Schematic

The production history and gradient survey data of well B(1) has been shown below.

Well		Bean Size (mm)	KLs of Oil	Water	Gas (m3/day)	THP (kg/cm2)
B(1)	BORE	6.5	42	0	7458	52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	40	0		52
B(1)	BORE	6.5	40	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	40	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52

B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		52
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		51
B(1)	BORE	6.5	42	0		50
B(1)	BORE	6.5	42	0		50
B(1)	BORE	6.5	42	0		50
B(1)	BORE	6.5	42	0		50
B(1)	BORE	6.5	42	0		50
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49

B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		49
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		56
B(1)	BORE	6.5	42	0		56
B(1)	BORE	6.5	42	0		56
B(1)	BORE	6.5	42	0		54
B(1)	BORE	6.5	42	0		54

Table 14: Production history of B(1)

		B(1) (FBHP)						
MD(m)	**MD(ft)**	**TVD(m)**	**TVD(ft)**	**Pressure (psia)**	**Temp(Deg C)**	**Temp(Deg F)**	**Pressure Gradient(psia/ft)**	**Temperature Gradient(Deg F/ft)**
0	0	0	0	796.42	29.89	85.80		
100	328.1	100	328.100	840.46	32.43	90.37	0.134	0.014
200	656.2	199	652.919	862.32	33.93	93.07	0.067	0.008
300	984.3	299	981.019	898.97	35.690	96.24	0.112	0.010
400	1312.4	396	1299.276	940.48	37.58	99.64	0.130	0.011
500	1640.5	489	1604.409	979.66	39.43	102.97	0.128	0.011
600	1968.6	574	1883.294	991.78	40.91	105.64	0.043	0.010
700	2296.7	656	2152.336	1040.59	42.61	108.70	0.181	0.011
800	2624.8	741	2431.221	1084.14	44.23	111.61	0.156	0.010
900	2952.9	820	2690.420	1122.3	45.57	114.03	0.147	0.009
1000	3281.0	905	2969.305	1174.68	46.9	116.42	0.188	0.009

1100	3609.1	987	3238.347	1218.28	48.09	118.56	0.162	0.008
1200	3937.2	1071	3513.951	1258.25	49.14	120.45	0.145	0.007
1300	4265.3	1155	3789.555	1312.77	50	122.00	0.198	0.006
1400	4593.4	1237	4058.597	1368.45	50.66	123.19	0.207	0.004
1484.5	4870.6	1307	4288.267	1422.31	51.4	124.52	0.235	0.006

Table 15: Temperature-Pressure Gradient Survey data of Well B(1)

7.3 Sand Production

The petro-physical properties of different sands of X-2 field have got high variation in their values. The Average values of porosity (Ø) and permeability (K) in this field lies in between 20-22% (ranges from 13-25%) and 25-30 mD (ranges from 4-200mD), respectively. These values indicate that the X formation has got good porosity and permeability which signifies that the wells can perform better if proper and successful stimulation and sand control jobs are carried out.

However, a reservoir having average porosity between 15-25 % is supposed to produce sand during production phase if completion is not optimized or drawdown is increased. The crude oil is light in nature with bottomhole temperature varies from 90 to 115^{0}C.

Serial No.	ASTM Sieve No.	Equivalent Mesh Size (micron)	Retention % (w/w)	Cumulative Weight %
1	16	1180	2.55	2.55
2	20	850	0.41	2.96
3	25	710	0.32	3.28
4	35	500	0.5	3.78
5	40	425	0.42	4.2
6	50	300	11.32	15.52
7	60	250	34.09	49.61
8	80	180	35.31	84.92
9	100	150	6.92	91.84
10	120	125	3.88	95.72
11	140	106	2.26	97.98

12	170	90	1.18	99.16
13	200	75	0.57	99.73
14	230	63	0.11	99.84
15	270	53	0.03	99.87
16	325	45	0.13	100
17	Pan	---	0	100

Table 16: Sieve Analysis data of Well C(1)

Serial No.	ASTM Sieve No.	Equivalent Mesh Size (micron)	Retention % (w/w)	Cumulative Weight %
1	16	1180	0.45	0.45
2	20	850	0.86	1.31
3	25	710	0.62	1.93
4	35	500	0.92	2.85
5	40	425	0.57	3.42
6	50	300	4.2	7.62
7	60	250	10.89	18.51
8	80	180	44.06	62.57
9	100	150	25.1	87.67
10	120	125	9.91	97.58
11	140	106	2.11	99.69
12	170	90	0.27	99.96
13	200	75	0.03	99.99
14	230	63	0.01	100
15	270	53	0	100
16	325	45	0	100
17	Pan	---	0	100

Table 17: Sieve Analysis data of Well C(2)

Serial No.	ASTM Sieve No.	Equivalent Mesh Size (micron)	Retention % (w/w)	Cumulative Weight %
1	18	1000	0. 85	0.85
2	20	850	4.7	5.55
3	25	710	7.01	12.56
4	35	500	28.43	40.99
5	40	425	13.91	54.9
6	60	250	35.53	90.43

7	70	212	5.58	96.01
8	80	180	2.05	98.06
9	100	150	1.11	99.17
10	140	106	0.54	99.71
11	170	90	0.13	99.84
12	270	53	0.13	99.97
13	325	45	0.03	100
14	400	38	0	100
15	Pan	-----	0	100

Table 18: Sieve Analysis data of Well C(3)

Serial No.	ASTM Sieve No.	Equivalent Mesh Size (micron)	Retention % (w/w)	Cumulative Weight %
1	18	1000	2.45	2.45
2	20	850	0.51	2.96
3	25	710	0.36	3.32
4	35	500	0.58	3.9
5	40	425	0.52	4.42
6	60	250	7.6	12.02
7	70	212	33.28	45.3
8	80	180	25.45	70.75
9	100	150	21.31	92.06
10	140	106	5.32	97.38
11	170	90	1.12	98.5
12	270	53	0.08	98.58
13	325	45	1.3	99.88
14	400	38	0.12	100
15	Pan	-----	0	100

Table 19: Sieve Analysis data of Well C(4)

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