KPU International Journal of Engineering & Technology
Volume 5, Issue 1, Mar. 2025
e-ISSN:2790-0819, p-ISSN:2790-0800

Date Received: 2024-08-21
Date Accepted: 2025-01-30
Date Published: 2025-03-30

Analysis of Challenges and Solutions in the Oil Extraction Process of the Qashqari Mining Field, Sar-e Pol Province, Afghanistan

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Abstract

In 1958, under an agreement between the former Soviet Union and Afghanistan, exploration and production activities in the northern part of Afghanistan were initiated which leaded to the discovery of significant oil and gas. The initial assessment of the Qashqari mining field was 19.6 million tons, with a recoverable reserve of around 6 million tons. In this mining area, 10 oil extraction wells have been drilled previously, and 10 recently. Oil production continues from previously drilled exploratory and appraisal wells, extracting 1400 tons of oil in 24 hours. Continuing extraction from exploratory wells using non-technical methods will lead to lower recoverable reserves, early saturation of wells, erratic progression of the water and oil contour, and negative impacts on the national economy.
The study will analyze the factors affecting the porosity and permeability of the Qashqari mining field and propose strategies to increase and optimize the production of recoverable oil from the reservoir by using a smaller number of wells. The current use of oil extraction techniques is also assessed through fieldwork, library research, and data analysis, propose and highlighting the technical extraction techniques which are crucial for the sustainable exploitation of Afghanistan's oil resources.

Keywords: Wells Debit, Geological Reserve, Extractable Reserve, Underbalanced Well Drilling Method, Hydrostatic Pressure, Premature Waterlogging.

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1. Introduction

The Qashqari block is located in the southern part of the center of Sar-e-Pol province. The region encompasses an area of 1,723 km^2 and is located in the Amu Darya basin's southern and southeastern sides. This is where the Angut, Qashqari, and Aqdarya oil fields are also situated.

From a geological perspective, the aforementioned mines are positioned within the elevated terrains of the northern part of Afghanistan. The discovery was made through the drilling of Well No. 1 in the Angut region, which led to the identification of the Alb, Apt, and Gatarif oil mines. Subsequently, this operation facilitated the attainment of an industrial-scale flow of crude oil.

Beginning in the early 1980 to 1992, a modest-scale oil extraction operations commenced from the Angut field, serving as a fuel source for the Kabul Microrayoon heating center, Kabul Polytechnic University, Kabul Auto-mechanic Technical Institute, and Mazar-e-Sharif Oil and Gas Technical Institute. However, from 1992 to 2002, due to significant political changes, non-technical oil extraction increased in this area. Consequently, a majority of the wells have since become inundated with water, resulting in an extraction composition where over 55% is water.

Commencing from the contractual agreement dated December 26, 2011, the China National Petroleum Company (CNPC), in collaboration with its Afghan partner, Watan Group, oil extraction initiated from five exploratory and appraisal wells of the Qashqari mining field. According to this contract, the mentioned company carried out 2D geophysical research in an area of 31 km2, and 3D research in an area of 6.57 km2. By activating 5 oil wells, this company undertook the drilling of well No. 21 in the Qashqari mining field and the repairment of well No. 12 in the Angut mining field. However, in 2016, contractual disputes led to the cessation of extraction activities and the contract's termination. Subsequently, in early 2022, the Ministry of Mines and Petroleum of Afghanistan started oil extraction operations, with the help of Afghan engineers and staff. Since then, an average, of 200 to 220 tons of oil have been extracted from the form of the five wells in 24 hours, processed in local refineries, and distributed within domestic markets at certain prices. This initiative has significantly contributed to the nation's banking sector.

On 5 December 2022, a contract was signed with Afchin Company of China to extract oil from the oil fields of the Qashqari Block again. The company drilled 8 new wells at points 21 and 22 and extracted about 1,400 tons of oil from the previous 5 exploration wells and the newly drilled wells in 24 hours using a non-technical method. This has caused a reduction in strata pressure, premature waterlogging of oil wells, the majority of the oil reserves remaining in the strata, and a decrease in the flow rate of the wells.

2. Research Importance and Rationale

Extraction of oil from exploratory and appraisal wells without drilling extraction wells poses a significant risk of irreparable damage to the oil mines in the Qashqari mining field.

The importance of the research includes the examination of the extraction process and the factors that can potentially reduce the porosity and permeability of the oil-bearing layers.

Additionally, it investigates issues such as premature water-logging of the wells, reduction in the oil production coefficient, and the irregular development of the oil-water contour within the productive layers of the oil-rich Qashqari field. The study also aims to propose preventive measures to mitigate these challenges.
Therefore, before commencing the extraction process, it is crucial to prioritize the drilling of oil extraction. In addition, an appropriate extraction regime must be determined through comprehensive well testing. By following this sequence, the risks of premature water ingress into the wells are minimized, the oil is not trapped in the strata, strata pressure does not decrease soon, and the overall extractable reserves of the mentioned mining field are not diminished.

3. Research Goals

The primary goals of this research paper are to comprehensively investigate the process of oil extraction and analyze the factors that contribute reduction in porosity and permeability of the oil-bearing layers. Additionally, the study aims to examine the occurrence of premature waterlogging in wells, the subsequent reduction in the oil production coefficient, and the irregular development of the oil-water contour (boundary) within the productive layers of the Qashqari mining field.
Finally, the research seeks to provide reasonable extraction methods, to mitigate the occurrence of the abovementioned challenges, and to ensure the efficient and sustainable extraction of oil from the Qashqari mining field.

4. Research Methodology

The research methodology employed in this scientific research work involves conducting a field visit in order to observe the oil extraction process and to collect data of the oil extraction process from different mines within the mining field. The collected data is then reviewed, analyzed, and evaluated to assess the effectiveness and efficiency of the oil extraction process. These evaluations are based on both practical experiences and reliable scientific sources.
In addition to that, the investigation and evaluation of the factors affecting the process of oil extraction from the mines of this area is based on practical experience and proposes effective scientific and technical solutions to overcome any existing problems.

5. Literature Review

The Qashqari mining field is located in the northern high of Afghanistan, approximately 10 km south of the city of Sar-e-Pol, with a total area of 6.5 km2. The exploration process in this mining field was completed in 1976. To facilitate the extraction process, the Chinese company (CNPCIW) took a series of preparatory steps after receiving the field contract on December 26, 2011. This included drilling 10 of the field's exploration wells, installation of preliminary oil purification equipment, drilling cement bridges in 5 previous and 10 newly drilled wells, and installing X-Mass Trees at the wellheads. In particular, cement bridges were drilled in exploratory wells numbered 1, 3, 4, 9, and 10, with the installation of X-mass trees on the wellheads at the wellhead to initiate oil production.

The geological reserve of this mining field is estimated at 19.629 million tons, with an estimated extractable reserve of 6 million tons. Oil production from the Alb, Apt, and Gatarif reservoir rocks is currently continuing. Separators are used to precisely separate and measure the amount of extracted oil and gas. The pre-refining of the oil from mechanical materials, water, and gas takes place in the on-site separators. The gas separated from the oil is burned, while the collected oil is transported to the refinery and subsequently for sale to the market. Under the terms of the new contract, the Chinese company has been entrusted with oil exploration and production in an area of 454 km2, which includes the Qashqari, Zamarudsai, and Bazarkami areas. In addition, seismic surveys and the drilling of exploratory wells are also planned in this area.

Currently, the Qashqari mining area continues to produce an average daily oil production of between 200 and 220 m3. The wellhead pressure of well No. 4 was measured 40 atm, with a dynamic pressure of 20 atm. Further wells are connected to the Apt and Alb reservoir rocks. Ten (10) exploratory were drilled in this area. Notably, the Chinese company also drilled appraisal and exploration well No. 21, which is not yet perforated and ready for oil production.

In the new contract with Afchin Company dated December 26, 2022, oil exploration, exploration, and production works were carried out in an area of 4500 square kilometers, which includes Angut, Aqdarya Qashqari, Zamarudsai and Bazarkami areas. In addition, seismic surveys and drilling of production wells in the above-mentioned areas, as well as drilling of exploration and production wells in new constructions are also planned in this area. Currently, about 2021 tons of oil are produced in 24 hours from 5 previously drilled wells and 10 newly drilled production wells in the Qashqari area. Ten exploration and appraisal wells were previously drilled in this area and Afchin Company drilled ten extraction wells at points 21 and 22. Drilling of production wells at Point 23 is also planned and work is underway. Currently, the said company produces about 2,021 tons of oil in 24 hours from the mines in this area and sells the oil to private companies for $500 per ton. In the early days of the Islamic Emirate of Afghanistan, 160 to 200 tons of oil were produced in 24 hours. The Ministry of Mines and Petroleum transferred this produced oil to the Ministry of Defense and the Ministry of Interior. In 24 hours, 1400-1500 m3 of the gases methane (CH4), carbon dioxide (CO2), and hydrogen sulphide (H2S) are produced, as well as the oil, which was burned in Pakal due to its small quantity. From well number 1, 42 cubic meters of oil were produced within 24 hours under a 5 mm choke. In other wells, 4 mm chokes were installed. In well number 10, the water content is 1.8% and in well number 9, the water content is 1.9%. The product extracted from other wells does not yet contain any water. On January 5, 2023, the Islamic Emirate handed over the territory to Afchin, a new Chinese company. This company carried out the exploration and exploration work in the three provinces of Sheberghan, Sar-e-Pul, and part of Maimana. The predecessor company had invested $200 million in these areas. The pre-refining facilities and four oil storage tanks, each with a capacity of 1,000 cubic meters, were built by the previous Chinese company in 2012; The oil is transported in tank trucks with pumps and flow meters. The oil in this area has a density of 0.86 to 0.70 grams per cubic centimeter. From 2012 to 2016, the former Chinese company produced more than one hundred thousand tons (100,000 tons) of oil. Currently, ten new production

wells have been drilled at points 21 and 22 in the Qashqari oil field, and production wells are also underway at point 23. Production now continues from wells 1, 3, 4, 9, 10, and the previous 10 newly drilled wells. Under the new contract, Afchin Company will invest $165 million in the first year and increase the investment to $540 million over the next three years.

Currently, Afchin Company extracts about 1,400 tons of oil from the region's mines in 24 hours and sells it to private companies for $500 per ton of oil. In 2021, 160 to 200 tons of oil were produced in 24 hours, and the Ministry of Mines and Petroleum of Afghanistan transferred this produced oil to the Ministry of Defense and the Ministry of Interior. In 24 hours, in addition to oil, 1400-1500 m3 of methane (CH4), carbon dioxide CO2, and hydrogen sulfide (H2S) are produced, which were burned during the renovation due to their small amount. Well #1 produced 42 cubic meters of oil in 24 hours under a 5mm choke or 4mm choke. The water content in well number 10 is so far 1.8% and in well number 9 the water content is 1.9%. Due to a treaty with the Chinese, the Islamic Emirate stopped mining and handed the area over to the Afchin Company. The Afchin Company took over the exploration and exploration work in the three provinces of Sheberghan, Sar-e-Pul, and part of Maimana for 200 million euros. The pre-refining facilities and four oil storage tanks, each with a capacity of 1,000 cubic meters, were built in 2012 by a former Chinese company. The oil is transported in tankers with pumps and flow meters. The oil in this area has a density of 0.86 to 0.70 grams per cubic meter.

Currently, 10 new production wells have been drilled at points 21 and 22 in the Dar Qashqari oil field, and 10 additional production wells are also underway at point 23. Production continues from wells No. 1, 3, 4, 9 and 10. Well No. 2 was drilled outside the contour and had no oil. Under the new contract, Afchin Company will invest $165 million in the first year and increase the investment to $540 million over the next three years.

6. Addressing challenges and implementing effective solutions in the oil extraction process at the Qashqari mining site

The geological structure of the northern part of Afghanistan, including the Qashqari, Aqdaria, and Angut areas, is characterized by the presence of Paleozoic, Mesozoic, and Cenozoic eras rock. In 1976, an exploration project was undertaken for the Qashqari oil field, which resulted in the drilling of nine wells in this mineral-rich region by July 1, 1978.

The iso-hypes of the Qashqari symmetric anticline span a height of 1000 m and dimensions of approximately (2.5×8) km2 (Figure 1). At the top of this structure, Bukhara limestone sediments of age Paleogene g (1ᵽ-K2) have been exposed to the surface.

In 1976, by drilling exploratory well No. 1, the sediments of the Qashqari mining area were identified as industrial. Subsequently, wells 1 to 8 were drilled in the same area in subsequent years, resulting in evidence of industrial use of the Hatrivian (XIV), Aptian (XII), and Lower Albian (XIa) reservoir rocks. Measurements at the wellhead were between 36 and 45 atm. Notably, the reservoir rocks of (XIV) from Gatarif had a porosity of and a permeability in the range of 40–100 mD (Darcy Milli).

The stratified water in the target mining area is characterized by the presence of sodium-hydro-carbonate in its composition. Extensive calculations have already been carried out in the region to calculate recoverable oil reserves, which have been estimated at more than 5.6 million tons. To ensure the accuracy of these estimates, production wells should be drilled in the area.

In Well No. 4, the Hatrivian reservoir rock thickness was measured to be 151 meters. The lithological composition of the Gatarif layer is mainly composed of sandstones, siltstones, and silts. Likewise, the sediments of the Aptian layer consist predominantly of sandstone, siltstone, silt, and with partial inclusion of limestone. In addition, a new production well No. 21 with a depth of 1730 meters was recently drilled. Given the goal of optimizing oil production in this area, several more production wells should also be drilled in this area. In accordance with best practices, the underbalanced drilling method is strongly recommended for these subsequent drilling operations [1]

The experiences of the last decades clearly demonstrate the significant influence of the selection of the appropriate drilling fluid when drilling the productivity layers. There are numerous cases where oil and gas did not flow from wells drilled with unmodified drilling solutions with related chemical additives.

Conversely, oil flow was obtained a high flow rate has been obtained from the neighboring wells drilled with high-quality drilling fluids, which demonstrates the critical role of drilling fluid selection in achieving optimal results. During testing the productive layers of the well, considerable amounts of oil and gas have often been observed within the productive layers. However, after cementing and perforating the installation column, the flow rate of oil and gas decreases due to changes in the properties of the productive layers and absorption of the drilling and cement solution by the productive layers.

When testing wells, significant flows of oil or gas are often extracted from the productive layers. However, for conservation reasons, these wells are subsequently filled with drilling fluid. With future use, their flow rates will decrease significantly, and sometimes no oil or gas flow will be achieved at all. Therefore, significant efforts and financial resources must be invested to achieve the initial volume of oil and gas.

The productive strata of the Qashqari mining field consist mainly of fine- and medium-grained sandstones with clay. The clay and carbonate components in these layers react with the liquid phase of drilling and cementing fluids and cause clay minerals to expand. As a result, the porosity and permeability of the oil-bearing layers decreases and oil production from these deposits requires the drilling of additional wells.

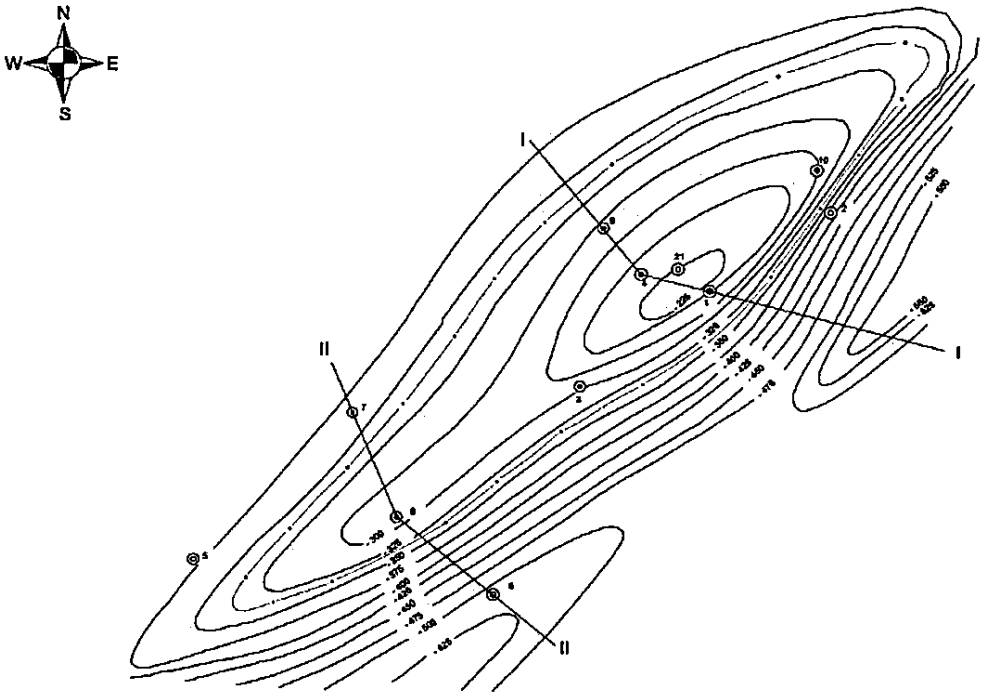


Fig. 1. A structural-geological map of the Qashqari mining field.

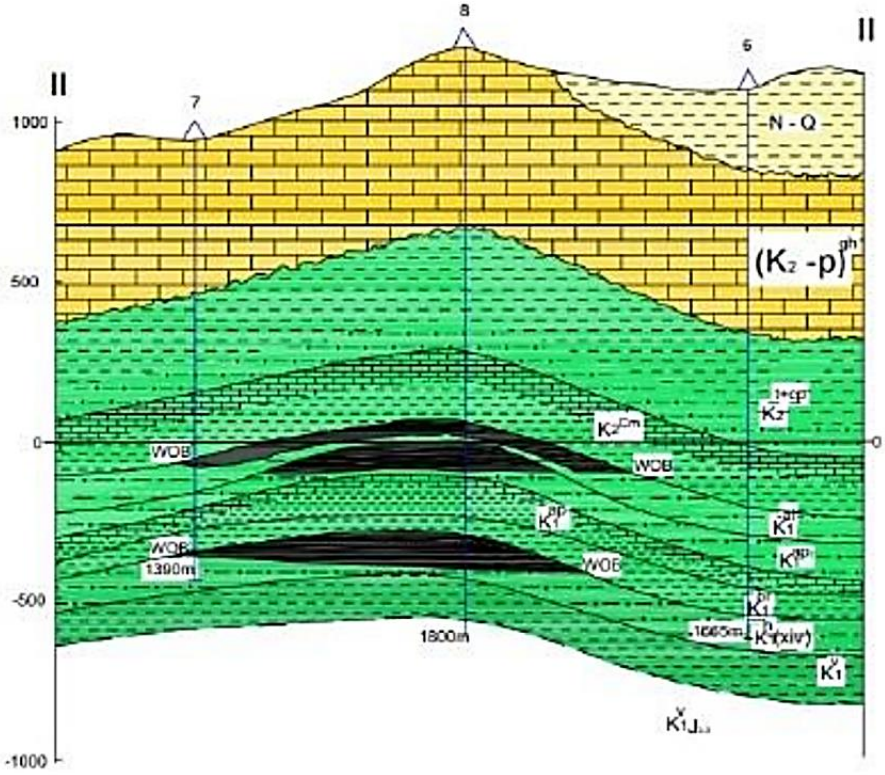


Fig. 2. Geological cross-section of the Qashqari oil field.

As a result of the penetration of drilling mud and cement solution into the sandstones of the productive layers of the Qashqari oil field, the oil is forced from the area surrounding the well into the interior of the layer, where its droplets combine with the oil and form an emulsion. The wetting and increase in the volume of clay and limestone particles in the oil layers of the Qashqari field leads to the formation of insoluble sediments around the wellbore, drilling mud and cement solution in the layers, and the formation of paraffin and other hard sediments. Penetration of drilling mud into the area around the bottom of the wellbore, causes the channels and pores of the oil-rich layers to become clogged. The longer the drilling time of the productive layers of this oil field increases, the more the drilling mud influences the porosity and permeability of the oil layer and pollutes and damages it. Therefore, the drilling of production wells and the development of oil deposits in Qashqari should be completed in the shortest possible time [5, 9, 10].

In the overbalanced drilling method, the hydrostatic pressure of the drilling mud in the wellbore is set higher than the pressure of the productive layer in order to contain the fluids in the reservoirs. Since the hydrostatic pressure of the drilling mud in the borehole is higher than the reservoir pressure, the liquid phase is filtered and its solid phase penetrates into the oil-bearing layers and clogs their cavities and pores [3, 9, 10].



Fig 3. Water ponds in the Qashqari mining field

Depending on the difference between the pressure of the layers and the solution, the following three conditions can be established for the drilling operations of the production wells in this area:

A. When the hydrostatic pressure of the drilling fluid is higher than the pressure of the layer ($P_{mud} - P_f > 0$), the drilling fluid penetrates the layers and reduces their porosity and permeability in the area of the well, which consequently leads to a reduction in the flow rate of the wells and the oil production coefficient of the

productive layers. This reduces the production rate, increases production time, and causes the areas around the well to become contaminated and impermeable.

B. When the layer pressure and the hydrostatic pressure of the drilling solution (PMud-Pf=0) are equal, the drilling method is called balanced drilling. In this case, the liquids in the layers are neither blown-out nor the drilling fluid absorbed. Since the pressure of the layers cannot be estimated before drilling, an attempt is made to restore the productive layers using the overbalanced drilling method with a small pressure difference of about (200 psi) or (Pmud=Pf+200 psi) that accommodates the drilling fluid, which penetrates into the rock layers and clogs and contaminates them due to the porosity and permeability of the oil-bearing rock layers.

C. If, when drilling the productive layers, the hydrostatic pressure of the drilling fluid is set lower than the layer pressure (Pmud-Pf <0), this drilling method is referred to as "underbalanced". In this method, the wellhead is equipped with a special device (preventor) to control the pressure of the layers and thereby achieve a high drilling speed [4].

The use of the modern underbalanced drilling method with blowout preventer (BOP) began in 1988 in the North Sea. The Shell company has used this method in several parts of the world and found that well production is several times higher than with the balanced drilling method. In some cases, drilling using the balanced method has also demonstrated an increase in mineable reserves. In Iran, studies on the use of underbalanced drilling technology began in 1998 and lasted until 2002. Subsequently, the necessary equipment and machines were designed and manufactured.

When opening the reservoir rocks using the underbalanced drilling method in the Qashqari oil mining field, the cost can be reduced in the following cases:

- The drilling speed will be ten (10) times higher than that of the overbalanced drilling method.
- Since the pressure of the drilling mud is kept lower in this method, it prevents an increase in the hardness of the drilled rock, increases the life of the drill bit, and increases the drilling speed of the well.
- Drilling mud and cementing fluid do not penetrate the oil-bearing layers. This will maintain the porosity and permeability of the reservoir rock and, as a result, recoverable reserves and well production will be higher.
- A thick crust of drilling mud will not form on the well wall and the drilling column and drilling equipment will not be stuck inside the well.
- The production of hydrocarbons starts from the moment of drilling the productive layers and having the equipment, it can be collected and sent to production institutions.
- Due to the fact that oil extraction starts from the moment of the drilling of the productive layer, it is not necessary to complete the wells.
- During the drilling, the fluid of each productive and permeable layer entered the well and the productive intervals were determined, so there is no need to test the well.

- In this method, the produced fluids are placed in a certain closed path, thus environmental pollution is minimized [4.5.6,7].

Currently, drilling under the balanced method is mostly used for the following three main reasons:

1. Increasing the speed of drilling, reducing the absorption of the drilling solution to the oil-bearing layers, reducing the costs of drilling, and preventing sticking and clogging of the drill pipes.
2. Preventing damage to the porosity and permeability of oil-bearing strata and improving well production.
3- During the drilling of extraction wells with the under-balanced drilling method, oil can be extracted to the surface. Therefore, by drilling the productive layers of the Qashqari oil field with this method, valuable information can be obtained about the productive layers of the said field and its production status during the drilling of wells.

The drilling of productive layers with underbalanced drilling improves the evacuation of hydrocarbons from oil mines, ensures the use of available resources, and by drilling a small number of wells, mines are extracted and environmental pollution is minimized [3,6,8,9].

In order to extract oil from the oil-bearing layers of this mining area, it is necessary to drill several extraction wells. During the drilling of these wells, the productive layers should be opened with Burma solution based on hydrocarbons (underbalanced drilling) which is mentioned in the table of geological-technical instructions. Among the extraction wells, one is extraction well number (21) which was drilled by a Chinese company in 2013.

7. Results

1. Before the production process from exploratory and exploratory wells began, the production wells had to be drilled, and after testing the wells and determining the maximum allowable flow rate of the production wells, the oil production process began using the technical method.

2. The planning and drilling of the production wells were not technically carried out. Drilling of production wells should be carried out in such a way that first a vertical well is drilled to a depth of 500 meters and then diagonally towards the oil layers. This method saved 2,000 to 2,500 meters of drilling and thousands of dollars in unnecessary costs.

3. The production process should be technically adapted so that the maximum permissible discharge from the wells can be determined through tests on the production wells and applied in practice. With this method, the pressure of the layers as stored energy would not decrease so quickly and the process of free oil eruption would continue for a long time. In addition, authorities would not be forced to resort to the expensive method of gas or air extraction to extract oil.

4. By drilling production wells and determining the maximum allowable flow rate in the Qashqari oil field, the oil and water boundary regularly advanced towards the wells, the groundwater table did not form and the pressure in the strata did not decrease soon.

5. When conducting drilling and oil production in the Qashqari and Angut fields, due attention should be paid to environmental protection and safe operation aspects, as problems still exist in these cases.
6. During our visit to the Qashqari field, it was found that the flow meters had been installed since 2016 and had not yet been technically checked and some were not working. Therefore, when determining the amount of oil poured into the tankers, attention should be paid to the required accuracy.
7. The laboratory equipment used in the Qashqari field dates back to 2016 and does not have the required accuracy. This laboratory should be equipped with new and well-equipped equipment so that the required accuracy can be achieved in the amount of oil loaded and the determination of its properties.
8. Since 2016, oil stations and flow meters have been installed in the Qashqari and Angut areas. The operation of these devices should be technically checked and controlled to ensure their functionality.
9. In addition, the work is progressing very slowly so far. Afchin Company should pay close attention to conducting survey and exploration work (i.e. 2D and 3D geophysical surveys should be carried out more quickly) in the region and also train Afghan technicians to manage the oil production process.

8. Recommendations

1. In order to fully exploit the recoverable reserves in the Qashqari oil field, the progress of the oil and water boundary should be continuously investigated and studied through geophysical surveys of wells, and the oil production process should be technically controlled.
2. If oblique drilling equipment is available, subsequent production wells should be drilled using the underbalanced drilling method. By using this drilling method, the natural state of porosity and permeability of the oil-bearing layers is preserved, because the drilling mud and drilled rock have no driving force to penetrate into the productive layers, and only a few production wells can be drilled from above the oil-bearing layers, larger amount of oil can be produced.
3. By drilling production wells using the underbalanced drilling method, due to the preservation of porosity and recoverable Oil reserves produce a larger amount of oil from oil-bearing layers.
4. By drilling production wells and technically starting the production process in the Qashqari area, production wells such as the Angut oil field will not be irrigated prematurely and the huge costs of repairing new production wells will be avoided.
5. In the Qashqari and Angut areas, technical personnel should wear safety clothing, but this has not yet been given due consideration.
6. During our visit, it was found that the oil stations and the Angut and Qashqari areas were covered with dry grass, which in the event of a fire would cause irreparable damage to the mines, processing, and storage facilities in these areas. Attention should be paid to solving this problem.
7. In order to be able to react to adverse circumstances and accidents, technical and firefighting equipment should be deployed on site.

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