UDC 622.276; 622.279
IRSTI 52.47.27

https://doi.org/10.55452/1998-6688-2024-21-4-277-298

[1]*Zhaksylykov Zh.,
Oil and gas production operator, ORCID ID: 0009-0005-8120-7621,
*e-mail: z_zhaksylykov@kbtu.kz
[1]Samatov A.,
Oil and gas production operator, ORCID ID: 0009-0006-1238-2386,
e-mail: a_samatov@kbtu.kz
[2]Sharipov Zh.,
Director of the Geology and Reservoir Development Department,
ORCID ID: 0000-0002-5994-7421

[1]LLP "Exploration and Production QazaqGaz", Taraz, Kazakhstan
[2]LLP "QazaqGaz Scientific and Technical Center", Astana, Kazakhstan

ENHANCING RESERVOIR PRODUCTIVITY USING HIWAY HYDRAULIC FRACTURING METHOD AT AMANGELDI FIELD

Abstract

This project explores the application of hydraulic fracturing methods to enhance reservoir productivity at the Amangeldi field. The study focused on the advanced HIWAY method, which optimizes proppant placement to improve hydrocarbon recovery. Mathematical models were developed to evaluate key parameters of this technique and implemented using FracPro software, enabling detailed simulation and analysis. Data for this study were gathered from publicly available sources, including OnePetro and ScienceDirect, ensuring a comprehensive review of current practices and innovations. Additional information was obtained during dual training at the Amangeldi field, providing practical insights and aligning the models with field-specific conditions. Contributions from scientific journals further enriched the study, supporting the integration of theoretical and empirical approaches. The findings aim to guide future hydraulic fracturing operations and highlight the potential of the HIWAY method to maximize efficiency, reduce operational costs, and mitigate environmental impact. This project underscores the importance of combining advanced modeling with hands-on field experience to address challenges in reservoir management.

Key words: hydraulic fracturing, HiWAY method, Amangeldi field, FracPro software, comparison.

Introduction

The deposit is located in the Moyinkum district of the Zhambyl region of the Republic of Kazakhstan, 170 km north of the city of Taraz. Geographically, it is located in the southwestern part of the Moyinkum sands, which occupy the interfluve of Shu and Talas.

Orographically, the area is represented by the bumpy sands of Moyinkum with a relative excess of bumpy sand ridges in the north-west direction up to 20 m. The boundary of the sands in the south and south-east extends in a north-westerly direction, along it flows the Talas river, in the bottom part of which there are farmsteads and cattle breeding stations. The area of depositf is sparsely populated. The nearest settlement is the village of Uyuk, located 70 km to the south. The sources of water supply directly for the entire area of the deposit are wells and artesian wells, the water level of which is at a depth of 10–20 meters from the well head. The area of the deposit is connected by road with the villages of Akkol, Uk, Ulanbel, the district center of Moyinkum and the regional center – the city of Taraz. Air transportation is carried out from Taraz airport. Railway transportation is also carried out by rail, the nearest railway station is Zhambyl station.

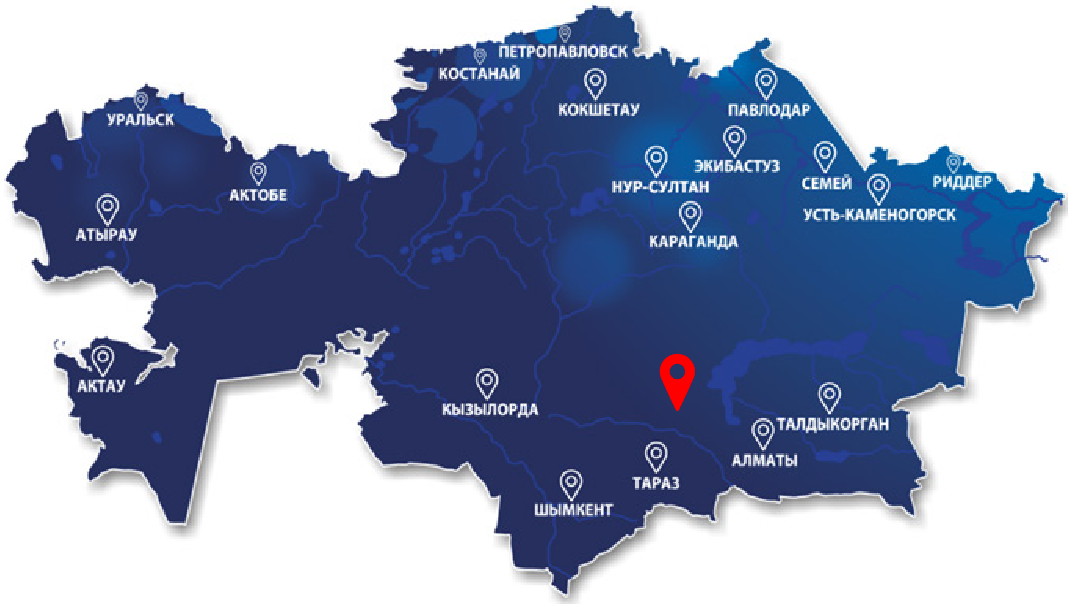


Figure 1 – Field location

The object of the development is the lower Visean productive horizon, within which three productive bundles (A, B, C) can be traced, which differ from each other by varying degrees of heterogeneity of productive layers and various capacitive filtration properties.

Pack A. The total thickness of the horizon, considering new wells, varies from 0.6 m to 16.8 m and averages 8.3 m. The number of isolated reservoir layers ranges from 1 to 6.

The total effective gas saturated thickness ranges from 0.8 m to 8.2 m and averages 4.3 m. The open porosity of reservoirs determined by well logging varies from 0.14 to 0.22.

In other wells, the reservoir layers are blocked. In wells, the gas-saturated thicknesses were 1.4 m, 2.7 m, 5.2 m, 3.6 m.

The coefficient of sandiness is 0.50, the coefficient of fragmentation is 2.6, the coefficient of propagation is 0.94.

Pack B is low-power and is separated from the overlying pack A by a clay section with a thickness of 4 m to 20 m. The total thickness of the bundle varies from 1 m to 5.6 m and averages 2.9 m. Within the bundle, there is mainly one reservoir layer, which is sometimes divided into two layers.

In other wells reservoir layers have been replaced by clay differences. The effective saturated thickness varies from 0.4 m to 4.6 m and averages 2.5 m. The open porosity according to well logging will change from 0.08 to 0.26.

The coefficient of sandiness is 0.64, the coefficient of fragmentation is 1.1, the coefficient of distribution is 0.70.

Pack C is the most sustained in terms of power is the stall in which it is separated from the overlying pack B by a clay interlayer with a thickness from 1.6 to 6 m, its spreading coefficient is 1.0

The total thickness of the bundle varies from 1.8 to 22.6 m, while the effective gas-saturated thickness varies from 1.8 to 19 m and averages 12.3 m. The open porosity of reservoir layers varies from 0.12 to 0.19.

The coefficients of sandiness and fragmentation are 0.80 and 2.5, respectively.

The weighted average porosity values for the object vary from 0.14 to 0.19.

The gas condensate deposit of the lower Visean sublayer was established according to the data of testing of almost all wells. In 1981, the gas-water contact was adopted at -1938 m in the middle of the distance between obtaining a weak gas inflow to (-1940 m) and an industrial gas inflow to -193.

In 1996, the inventory was recalculated, the WL processing was revised. Based on these materials, the GWC was adopted at -1972 m. It was adopted on the basis of testing, where in the first gas was obtained in an open trunk to an absolute mark of -1967.6 m, and in the second – reservoir water from an absolute mark of -1976.8 m, according to the results of interpretation of WL materials, the layers are estimated as water saturated from an absolute mark of minus 1968.6 m.

According to the calculation of reserves in 2007 , the gas-water contact was accepted at -1968 m along.

The gas condensate deposit is arched by type of reservoir, tectonically shielded. The size of the deposit is 14.8 x 7.5 km, height is 268.8 m.

Reservoir rocks have been studied from the core and from the interpretation of data from Well logging.

The sediments of pack A are represented by uneven layering of sandstones, siltstones and mudstones. Sandstone beige-gray, gray, fine-grained, medium-fine-grained, quartz-feldspar, feldspar-quartz, poorly and medium graded. Clay cement of pore and contact-pore type, calcite pore and corrosive, conformal incorporation. Siltstones are similar to sandstones in terms of the composition of the clastic material, as well as the type and composition of cement. Mudstones are gray, dark gray, often carbonate, strong and black carbonaceous, thinly layered, with layers of anhydrite, with mineral cracks filled with anhydrite. The reservoir rocks of pack A are represented by beige-gray sandstones, medium fine-grained, feldspar-quartz, medium graded. The mineral composition of the detrital part (85–90%): quartz (70–80%), feldspar (10–15%), fragments of effusions, quartzites. Cement (10–15%) contacts kaolinite, with sections of film chlorite-hydromodic. Porosity is associated with the formation of secondary voids in kaolinite cement and in kaolinized feldspar grains.

The deposits of pack B are represented by the interlayer of beige-gray sandstones and siltstones of dark gray, gray, clay, with abundant ORO inclusions, with layers of coals. The sandstones are medium-fine-grained, fine-grained feldspar quartz, medium and well sorted. Mixed clay cement is contact-pore, contact, calcite pore, and conformal-incorporation structures of cement are developing.

The reservoir rocks of pack B are represented by beige-gray sandstones, mainly fine-grained, feldspar-quartz. The sorting of debris is often good. The composition of the clastic material (90%) is dominated by quartz (90%), in a subordinate amount feldspar are effusive. Cement (10%) is kaolinite, chlorite-kaolinite pore-contact contouring with conformal-incorporation sections. There are aggregates of microcrystalline pyrite in the intergranular spaces. Secondary porosity is associated with microcracks in clastic grains, the opening of which reaches 0.008 mm, and voids (0.08–0.1 mm in size) in kaolinite cement.

Pack C is represented by gray sandstones, light gray-beige, fine-medium-grained, medium-grained, multi-grained, mostly massive, feldspar-quartz rocks, well and poorly sorted, with inclusions and thin layers of carboniferous vegetable detritus. The reservoir rocks of the pack C are represented by beige-light gray sandstones, mainly fine-medium-grained, feldspar-quartz, medium-graded. The detrital part (85–95%) contains quartz (up to 80%) feldspars (10) fragments of siliceous rocks, micro quartzites. The cement is mixed (5–15%) contact-pore, contact kaolinite, kaolinite-hydrous, conformally incorporated in sections. Porosity is associated with the formation of secondary voids (0.08–0.09 mm in size) in kaolinite cement and numerous microcracks in classical grains. The thickness of microcracks is up to 0.007 mm

Hydraulic fracturing (HF) has been employed to improve the efficiency of gas and gas wells since 1947. During the last seven decades, technology has experienced substantial changes to fulfill the aims and purposes of enhancing production in any situation.

Table 1.1 – Static series of permeability distribution

Pack	Parameters	The range of change in permeability $*10^{-3}$, micron							
		0,3–1	1–3	3–5	5–10	10–30	30–50	50–100	100–300
A	frequency	40	51	16	7	13	3	4	4
	relative frequency %	29.0	37.0	11.6	5.1	9.4	2.1	2.9	2.9
B	frequency	12	7	4	1		1	1	
	relative frequency %	46.2	26.9	15.5	3.8		3.8	3.8	
C	frequency	177	85	10	7	4	2		
	relative frequency %	62.1	29.8	3.1	2.6	1.6	0.8		

Literature review

Advancements in hydraulic fracturing technology have enabled the extraction of reserves from low-permeability and deep reservoirs, resulting in high gas recovery rates and improved fluid flow to the well. The objective of hydraulic fracturing in modern times is to not only generate a system of cracks in the rock, but also to control the beginning of these fractures and guarantee the highest level of permeability achievable following the treatment. The economic feasibility of typical hydraulic fracturing (HF) technologies is progressively restricted by the reservoir parameters in new field locations. Under these circumstances, it is advantageous to examine the worldwide expertise in the functioning and enhancement of such wells. A significant amount of knowledge has been gathered in the Eagle Ford Shale region in the United States. It is crucial to recognize that attaining the intended efficiency of well treatments necessitates the proper utilization of HF materials. Optimal production outcomes can only be achieved by the precise coordination of well completion techniques (including placement, determination of stage count, and perforation strategy) with hydraulic fracturing design.

The formations in many nations have fractures in hydraulic fracturing that are significantly far apart compared to other countries. The majority of wells in these countries have between 5 to 8 stages per well. Another distinction in domestic fields resulting from the hazards of gas-water interaction is the precedence of longitudinally oriented fractures in regard to the wellbore. When drilling horizontal wells, it is important to consider not only the risks of crack growth and barrier violations, but also the need to minimize friction losses in the wellbore and perforations. Failure to do so can result in early shutdown of operations and require significant time and resources to rectify the situation. Hence, the HiWAY cluster fracturing technology, which has undergone testing in over 25 countries worldwide.

HiWAY technology is an innovative form of hydraulic fracturing. The advancement of HiWAY technology is based on the absence of a direct correlation between the quality of propane and the effectiveness of hydraulic fracturing. This is achieved through the formation of open pathways within the crack, allowing for a substantial enhancement in the hydraulic conductivity of reservoir fluids in comparison to conventional methods. The proppant is unevenly distributed in the crack of the highway, forming proppant "columns" that are flanked by open channels.

The development of this technique was carried out by specialists at the Novosibirsk technique Center of Schlumberger. After conducting experiments to verify the increased conductivity of non-continuous proppant gaskets, the researchers focused on finding ways to create proppant columns in a well within an already existing crack. These columns needed to be able to withstand the stresses caused by fluid flow and closure cracks, while also keeping the drainage channels open. Various methods for forming proppant columns within a crack have been examined in model and experimental investigations. These methods include the utilization of thermomechanical memory alloy fibers to gather proppant grains in specific locations, as well as the implantation of encapsulated proppant.

The HiWAY technology utilizes fiber materials to enhance the suspension of proppant, preventing it from settling down from the upper part of the crack.

Once the fracture is sealed, the fibers disintegrate and rise to the surface without impeding the subsequent flow of hydrocarbons. Presently, the fibers being utilized are J579 and J659. The product is called Fiber J579. The fiber has a moderate temperature tolerance, with a maximum recommended usage temperature of 120°C. Beyond this threshold, the fiber will rapidly degrade. Phyber J659 is classified as a high-temperature additive. The maximum practical temperature of this product is 180 °C. Up to this temperature, the fiber remains stable and has a high load-bearing capacity. Beyond this temperature, the fiber degrades at a regular pace.

Hydraulic fracturing with open channels (HiWAY Fracturing)

Open channel hydraulic fracturing, sometimes referred to as HiWAY technology, is a cutting-edge method of hydraulic fracturing that enhances the effectiveness and long-term stability of fractures. The primary concept behind HiWAY technology is to generate "channels" within partially closed fractures using proppant. These pathways stay unclogged, allowing for efficient transmission of cracks and enhanced movement of hydrocarbons. This is accomplished by carefully dispersing the proppant within the fractures, enabling the formation of a stable proppant structure and the creation of open channels.The fundamental idea of this technology is generating fractures with permeable channels that facilitate the enhanced flow of hydrocarbons towards the well.

The following are the primary attributes and qualities of hydraulic fracturing utilizing open channels:

1) The HiWAY Fracturing method utilizes unique polymer granules that are included into the proppant. These granules undergo expansion during the fracturing process, resulting in the formation of open channels within the fractures. This expansion guarantees a continuous and uninterrupted flow of hydrocarbons.

2) The benefits of open channels include less hydrocarbon flow resistance, prevention of crack blockage, enhanced reservoir permeability, and improved long-term well productivity.

3) The precise dispersion of specialized polymer granules in cracks is a crucial feature of HiWAY technology. This is accomplished using specialized equipment that guarantees the most efficient blending and dispersion of granules within the hydraulic fracturing fluid.

4) Process control: HiWAY technology offers precise control over fracture formation and the distribution of open channels, which is a significant advantage. Engineers can optimize the fracturing procedure based on the precise geological conditions and characteristics of the well.

5) Enhancing long-term productivity: HiWAY Fracturing technique utilizes open channels to boost long-term well productivity and augment overall hydrocarbon production.Hydraulic fracturing with open channels, also known as HiWAY Fracturing, is a highly efficient technique for enhancing well productivity. It is utilized in diverse geological settings and plays a crucial role in optimizing the extraction of hydrocarbons.

Criteria for selecting a well for hydraulic fracturing.

Hydraulic fracturing effectiveness is determined by the degree of product waterlogging, the initial gas saturation of reservoirs, the effective capacity of the hydraulic fracturing interval, the heterogeneity of the formation structure and the fragmentation of its section, the isolation of the hydraulic fracturing interval by powerful clay layers, the location of injection wells, and the extent of reservoir flooding at the impact site, according to an analysis of the geological structure and the history of deposit development at the hydraulic fracturing sites. Given everything mentioned above, it is feasible to suggest using the following physical and geological factors for selecting low-water wells for hydraulic fracturing:

a) The initial gas saturation of reservoirs in the fracking interval is close to or above their possible saturation limit.

b) The effective power of the hydraulic fracturing interval is more than 3m.

c) The thickness of the underlying and overlapping hydraulic fracturing interval of clay layers is more than 5 m;

d) The thickness of the internal clay sections is less than 2m.

e) No more than 5–6 permeable interlayers with a capacity of more than one meter.

f) The water content of well products is less than 40%.

g) The water content of the products of the surrounding nearby wells is less than 70%

h) The potential flow rate of the well is more than 20t/day.

i) Extraction from the initial recoverable reserves at the well of less than 20%.

The technical condition of the well

The well needs to be sound technically. There cannot be any infractions or deformations in the production column between the packer landing. To prevent backflow during hydraulic fracturing, the cement ring's adherence to the formation rock and the operating column must be sufficient, at least 50 meters above and below the perforated interval.

Perforation interval

Not more than 20 to 25 meters should be the perforated interval. Otherwise, more scientific, and technological steps are needed to guarantee that the reservoir is covered by hydraulic fracturing.

Skin effect

The existence of a skin effect in a well after hydraulic fracturing is a good thing for raising its production. Usually, wells with low productivity in a setting of highly productive ones are where hydraulic fracturing produces its greatest impact.

The thickness of the formation and the thickness of the screens

Typically, the producing reservoir should have a minimum effective thickness of 3-5m. A crucial requirement for hydraulic fracturing is the existence of screens with adequate thickness and uniformity in the region, which operate as barriers between the productive reservoir and the reservoirs above and below. This is particularly significant when these reservoirs have high permeability and are saturated with water. The thickness of the screens required for effective isolation of the fractured formation is determined by the disparity in natural stresses between the screens and the formation, as well as the hydraulic fracturing technique employed. Plastic rocks, such as clays and siltstones, exhibit the highest levels of stress. The presence of higher amounts of sandy and siltstone material in clays, along with their conversion into clay minerals, results in a decline in shielding capabilities. Dehydration causes the shielding qualities of clays to decrease when they are compacted with depth. Typically, while conducting hydraulic fracturing at depths ranging from 1000 to 1800 meters, with a crack that extends up to 50 to 100 meters and an injection rate not exceeding 2.5 cubic meters per minute, it is recommended to use screens with a minimum thickness of 8 to 10 meters.

Removal of the well from the gas-water contacts

Hydraulic fracturing wells need to be placed sufficiently apart from the gas-water contact contours, typically at least as far apart as the wells themselves. Rapid flooding or gas breakout from the cap may happen if the producing well is closer to the gas content contour, particularly if the path of the hydraulic fracturing crack is perpendicular to the contour line.

Fragmentation of the formation

For hydraulic fracturing, a reservoir with a uniform permeability and adequate thickness is the ideal target. Hydraulic fracturing may be less successful if the productive reservoir segment is fragmented. In addition, mistakes in determining the length, shape, and width of the fracture as well as the technological impact of hydraulic fracturing might occur when building a hydraulic fracturing crack in a highly heterogeneous formation.

Formation depth

The hydraulic fracturing equipment's technical capabilities and the fixing material's strength dictate the greatest depth of the development object that can be reached by this method. The depth of the development object should not be greater than 2500–2800 meters when employing quartz sand. By using a stronger anchoring substance, the maximum depth that may be reached by hydraulic fracturing the development object is increased.

Materials and Methods

Using standard hydraulic fracturing methods, the investigation's key hydraulic fracturing parameters were calculated for the production well. The thickness (h) of the well is 36.5 meters, and its depth is 2152 meters. With a viscosity of 0.6 Pa·s and a density of 1100 kg/m³, 62 tons of proppant are injected into the fracture. Q = 3.2 m³/min is the injection rate.

Table 1 – Tubing parameters for calculations

Tubing			
External diameter (mm)	Weight (kg/m)	Inner diameter (mm)	Depth (m)
88.9	13.22	76	1146.18
73	9.16	62	2025

Table 2 – Well parameters for calculations

Well parametres	Values
Depth of the well, m	2142
Perforation interval, m	36.5
Initial diameter of tubing, m	0.075
Diameter of production the casing, m	0.178
Rock density, kg/m3	2900
The amount of fracture fluid, m3	282.4
Volume of the proppant, m3	53.33
Porosity of the cracks post-closure	0.17
Density of proppant, kg/m2	1100
Proppant permeability, m2	884*10^-12
Rock permeability, m2	0.0108*10^-12

Table 3 – Casing parameters for calculations

Casing			
External diameter (mm)	Weight (kg/m)	Inner diameter (mm)	Depth (m)
168	41.67	150.5	2282

The fracture is computed by hand selecting the well X, and using the algorithm created by I.T. Mishchenko. Fracture parameter computation is a difficult process with two essential components:

- Analyzing the fundamental elements of the procedure and ascertaining the necessary amounts of equipment for generating fracture segments
- Determining the classification of the fracture and doing measurements to determine its size.

The rock rupture pressure can be calculated using the formula provided below for an unfiltered fluid:

$$(1)\ P_{vert} = P_0 * g * H = 9.81 * 2142\ \text{m} * 2900\ \text{kg/m3} = 60.93\ \text{Mpa}\ (1)$$

where, P_0 – average density of the rock, H-depth of the well

Next, we calculate the horizontal component of the stresses using the following formula:

$$(2)\ P_{horiz} = P_{vert} * \eta * (1-\eta) = 60.93\ \text{Mpa} * 0.25 * (1-0,25) = 20.31\ \text{Mpa}\ (2)$$

$where, \eta$- poisson's ratio

As the depth increases, the vertical force exerted by the weight of the rocks above becomes more prominent. At greater depths, the vertical stress sometimes surpasses the horizontal stresses, leading to the formation of vertical fractures. Below depths of 1000–1500 meters, vertical strains typically exert greater effect than horizontal stresses, leading to the formation of vertical fractures as the most probable outcome of hydraulic fracturing. Within our given situation, the magnitude of the force pulling in the vertical direction is higher than the force acting horizontally, leading to the occurrence of a fracture in the vertical direction.

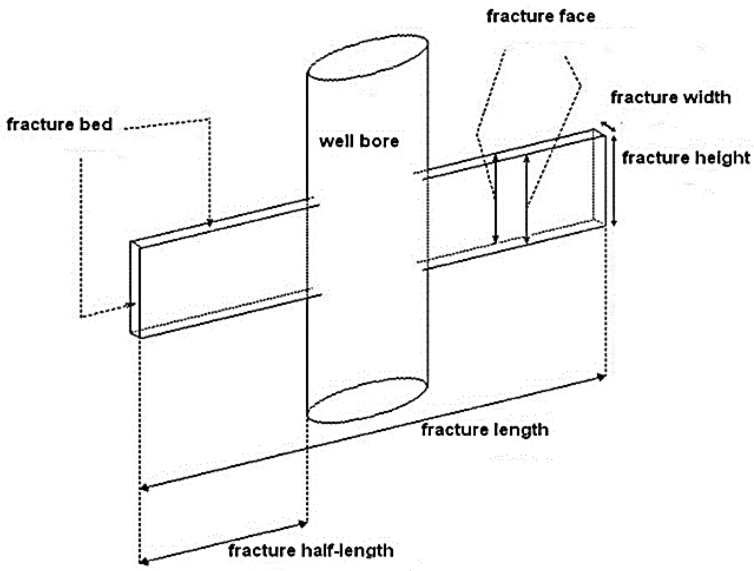


Figure 2 – Vertical fracturing

Fracturing pressure determination in the absence of fluid filtration:

$$(3)\ P_{frac} = P_{vert} - P_{reservoir} + P_s = 60.93\text{Mpa} - 15.19\text{ Mpa} + 1.5\text{Mpa} = 46.41\text{ Mpa}$$

Calculation of the required downhole pressure:

- $\frac{\text{Pbwh}}{\text{Phoriz}} * \left(\frac{\text{Pbwh}}{\text{Phoriz}} - 1\right)^3 = \frac{(5{,}25*(\text{E}^2)*\text{Q}*\text{u})}{(1-\eta^2)*(\text{Phoriz})^3*\eta} = \frac{5{,}25*(3{,}5*10^{10})^2*0{,}053*0{,}6}{(1-0{,}25^2)^2*(20{,}31*10^6)^3*382{,}7} = 0{,}000725$
- $x*(x-1)^3 = 0.000725$
- x=1.66
- $\frac{Pbwh}{Phoriz} = 1.0873$
- P_{bwh}=1.0873*20,31 Mpa=22.08 Mpa

where, u-Viscosity of the sand carrier liquid, Q-the rate of liquid injection,

E-Young's module, η – poisson's ratio

The length of the extent of fracture created by hydraulic fracturing (fracking) is crucial in evaluating the effectiveness of the technique. The length is determined by various parameters, including the injection pressure, the qualities of the fracturing fluid and proppant, and the geological characteristics of the reservoir. The calculation will be determined using this formula:

$$(4)\ L=\sqrt{\left(\frac{V*E}{5{,}6*(1-\eta^2)*h*(Pbwh-Phoriz)}\right)}=\sqrt{\left(\frac{382{,}7*3{,}5*10^{10}}{5{,}6*(1-0{,}25^2)*37*((22{,}08-20{,}31)*10^6)}\right)} = 200\text{ m}$$

where, V- volume of liquid for rupture, E-Young's module, h - perforation interval, η-poisson's ratio

The crack length, fracture breadth, and residual width are crucial characteristics that determine the success of the HF treatment. They indicate the width of the fracture when it is open and any changes that occur to it once the process is finished. The width of the fracture is influenced by important elements such as the pressure of the injected fluid, the qualities of the rock, the characteristics of the fluid, and the conditions of the hydraulic fracturing process. The remaining width of the fracture following hydraulic fracturing (HF) can also function as a significant indicator of fracture integrity and its capacity to hold proppant. An assessment can be conducted by employing this mathematical equation:

(5) $W= (\frac{(4*(1-\eta^2)*L*(Pbwh-Phoriz))}{E} = \frac{(4*(1-0{,}25^2)*200*(22{,}08-20{,}31)*10^6)}{3{,}5*10^{10}}$ =0.037 m = 3.7 cm

Residual crack width:

(6) $W_1=(W*n0)/(1-m)$ =(0.037*0.008)/0.83=0.0035 m=0.35 cm

here, m ' represents the porosity of the cracks post-closure,while n0 denotes the volume fraction of proppant within the mixture.

The permeability of cracks in hydraulic fracturing refers to their ability to enhance the flow of fluids. It acts as a crucial measure indicating the effectiveness of the HF method in increasing reservoir productivity. Fracture permeability is influenced by various parameters, including fracturing pressure, rock properties, selection of fracturing fluid, and distribution of proppant. Enhanced permeability indicates a better connection between cracks and the reservoir, resulting in enhanced fluid flow and subsequently higher production rates. We shall compute it using this equation:

$$K1=\frac{W1^2}{12*10^4} = \frac{0{,}0035^2}{12*10^4} = 0.066*10^{-12}\ м^2 = 100\ \text{Darcy}$$

In addition to assessing the permeability of fractures, it is essential to estimate the permeability of the zone surrounding the wellbore, commonly known as the near-well or near-wellbore zone. This area is of great significance in reservoir operations as it has a direct impact on the movement of fluids from the reservoir into the wellbore. For our specific situation, the answer is:

$$(7)\ K2=\frac{((\pi*D-W1)*k+W1*K1)}{\pi*D} = \frac{((3{,}14*0{,}15-0{,}0035)*0{,}0108*10^{-12}+0{,}0035*101*10^{-12})}{3{,}14*0{,}15} =$$
$$= 0.768*10^{-12}\ m^2 = 752\ mD$$

Where, D is the diameter of the well, m, k is the permeability of the reservoir.

The next is volume of liquid for injection:

$$(8)\quad V_{inj} = 0.785*d\ in*H = 0.785*0.076^2*2087 = 9.5\ m3$$

The hydraulic fracturing process takes a total of 2 hours. At this juncture, a high-pressure fluid is introduced into the well in order to generate cracks in the rock formation. This phase encompasses the installation, introduction of fracturing fluid, and following procedures. A reduced timeframe could suggest a more efficient fracturing process, potentially resulting from enhanced equipment and processes, or less complex geological conditions. Optimizing time management is essential in hydraulic fracturing operations to minimize expenses and environmental consequences while optimizing the extraction of resources. The estimation will be calculated using this formula:

$$(9)\ t = \frac{Vliq+Vinj}{Qa} = \frac{382.7+9{,}5}{3.2} = 122.57\ \text{min}$$

where, Q_a– injection rate`

Dimensionless conductivity is a critical characteristic that indicates the efficiency of hydraulic fracturing. The non-dimensional conductivity parameter is commonly used to assess the effectiveness of the fracturing process by measuring the fractures' capacity to transport fluid. The calculation takes into account multiple parameters, including fracture geometry, fluid characteristics, and reservoir conditions. A higher dimensionless conductivity signifies enhanced connectivity between the wellbore and the reservoir, facilitating greater fluid movement and improved production rates. The dimensionless conductivity is crucial in evaluating the effectiveness of hydraulic fracturing operations and maximizing the performance of the reservoir.

$$Cd = \frac{kf*w}{k*xf} = \frac{884*10^{-12}*0{,}086}{0{,}0108*10^{-12}*101} = 30$$

The primary determinant of the outcome of hydraulic fracturing is the anticipated impact of the process. This result reveals the degree to which the current flow rate of the well has increased as a result of hydraulic fracturing. Within our specific context, this computation is carried out in the following manner.

$$n = \frac{Q1}{Q2} = \frac{Lg\frac{(Rk)}{rc}}{Lg\frac{(2*Rk)}{rm}} = \frac{Lg\frac{(400)}{0{,}075}}{Lg\frac{(400)}{\frac{200}{2}}} = 4.12$$

where, Rk is the radius of the supply circuit, m; rc is the radius of the well, m; rm is the half of the crack length, m

Ultimately, using the use of mathematical computations, we successfully ascertained many crucial factors of hydraulic fracturing, such as permeability, fracture length, fracture width, and other characteristics. In addition, we evaluated the conductivity of the cracks, the dispersion and density of the proppant, and the variations in reservoir pressure.

Table 4 – Results of calculation for SLB (HIWAY)

Parameters	Values
Half the length of the cracks	97.4 m
Residual crack width	3.5 mm
Dimensionless conductivity	30
Effect of hydraulic fracturing	4.12
Duration of hydraulic fracturing	134 min
Crack permeability	752 mD

Upon concluding the calculations, the findings reveal a substantial rise in permeability from 10.18 mD to 752 mD, hence showcasing the exceptional efficacy of the hydraulic fracturing procedure. In addition, the impact of hydraulic fracturing is seen in a 4.12-fold rise in the productivity index. The significant enhancement highlights the efficacy of the fracturing procedure in improving the performance of the well and the overall production of the reservoir.

Moreover, the fracture length and width were assessed to be ideal, guaranteeing good communication between the reservoir and the wellbore. An assessment was conducted on the dispersion of the proppant, which verified its ability to effectively uphold the cracks and sustain enhanced permeability. These findings emphasize both the technological achievement of the hydraulic fracturing procedure and its capacity to greatly enhance the retrieval of hydrocarbons and commercial profits.

Table 5 – Results of calculation for Trican

Parameters	Values
Half the length of the cracks	89.5 m
Residual crack width	2.3 mm
Dimensionless conductivity	18.8
Effect of hydraulic fracturing	3.7
Duration of hydraulic fracturing	130 min
Crack permeability	657 mD

Results and Discussion

Our research aims to determine the optimal hydraulic fracturing (HF) approach. To do this, we have undertaken the task of calculating the required parameters for Trican, a company experienced in this industry and known for employing conventional HF techniques. We assessed various important characteristics, such as permeability, fracture length, and width, along with the productivity index before and after the hydraulic fracturing treatment. Our goal is to establish the most effective way by comparing these parameters with those achieved utilizing more sophisticated HF techniques. Trican's conventional HF technique involved collecting data on the starting state of the well, treatment pressures, properties of the fluid and proppant, and production rates after the treatment. This extensive research enables us to compare the performance metrics of conventional approaches with contemporary alternatives, guaranteeing a comprehensive evaluation of the efficiency of each methodology in improving well production and economic feasibility.

After doing a comparative analysis of the mathematical computations for both companies, we determined that Hiway's hydraulic fracturing (HF) yielded the most favorable outcomes in terms of all essential factors. Our comprehensive investigation involved assessing the enhancements in permeability, fracture dimensions (length and width), improvements in productivity index, and total output rates. Hiway's improved approach exhibited superior performance compared to Trican's conventional methods in all aspects.

We proceeded to simulate all the data using FracPro. The simulation findings, which included important parameters, closely matched our predicted values. The agreement between the simulation results and our computations provides additional support for the accuracy of our study. It shows that our mathematical models effectively represent the behavior of the hydraulic fracturing process and its influence on reservoir performance. We are dedicated and reliable, instilling trust in our analysis and its practical implementation in real-world situations.

Table 6 – Results from FracPro

Parameter, for the updated model	Optimized design	Error
Impregnated crack half-length, m	100.9 m	0.9 %
Crack width	3.8 cm	2.63 %

Fracpro is a comprehensive software package designed specifically for hydraulic fracturing operations within the oil and gas industry. It's utilized by engineers, geologists, and other professionals involved in the planning, design, and optimization of hydraulic fracturing treatments.

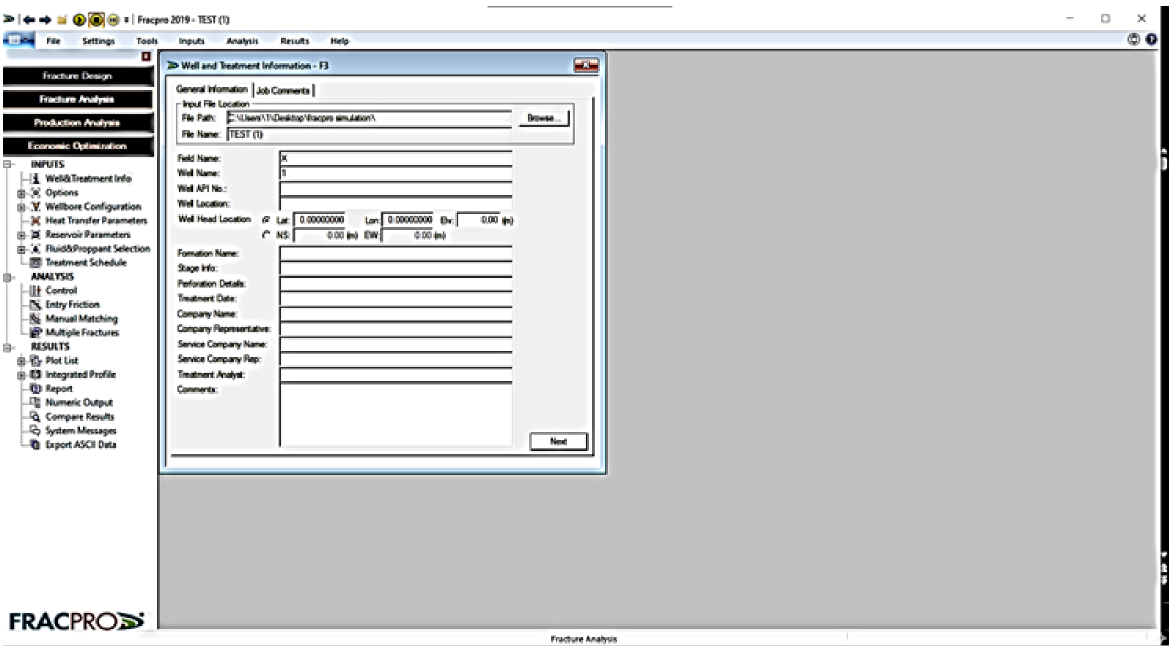


Figure 3 – FracPro software general well input data

The "Menu Bar" consists of common options such as File, Settings, Inputs, Analysis, Results, and Help, which are used for browsing and setting the software. The "Toolbar" comprises of icons that provide easy access to numerous functions.

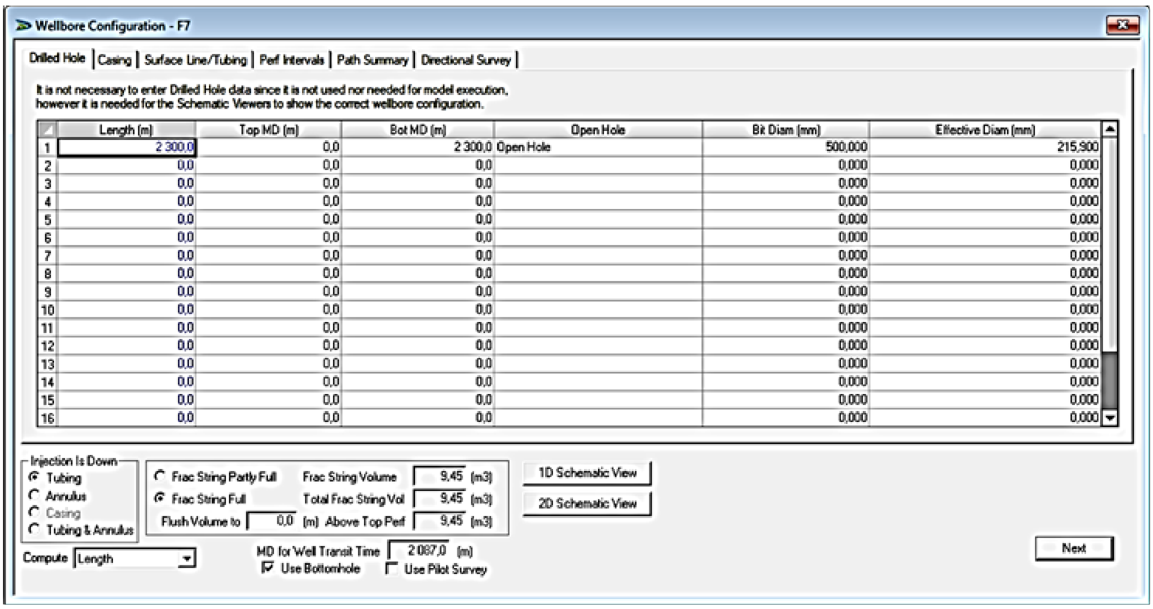


Figure 4 – Drilled Hole

The Drilled Hole tab is utilized for inputting the precise geometry of the hole after it has been drilled. The data presented on this tab does not contribute to any of the computations performed in Fracpro. This information is exclusively utilized for the Schematic View screen, the 2D Schematic View screen, and the 3D Wellbore Viewer screen. These screens can be accessed either from the icon bar or by selecting "View" from the main top menu. In this project, total length 2300m.

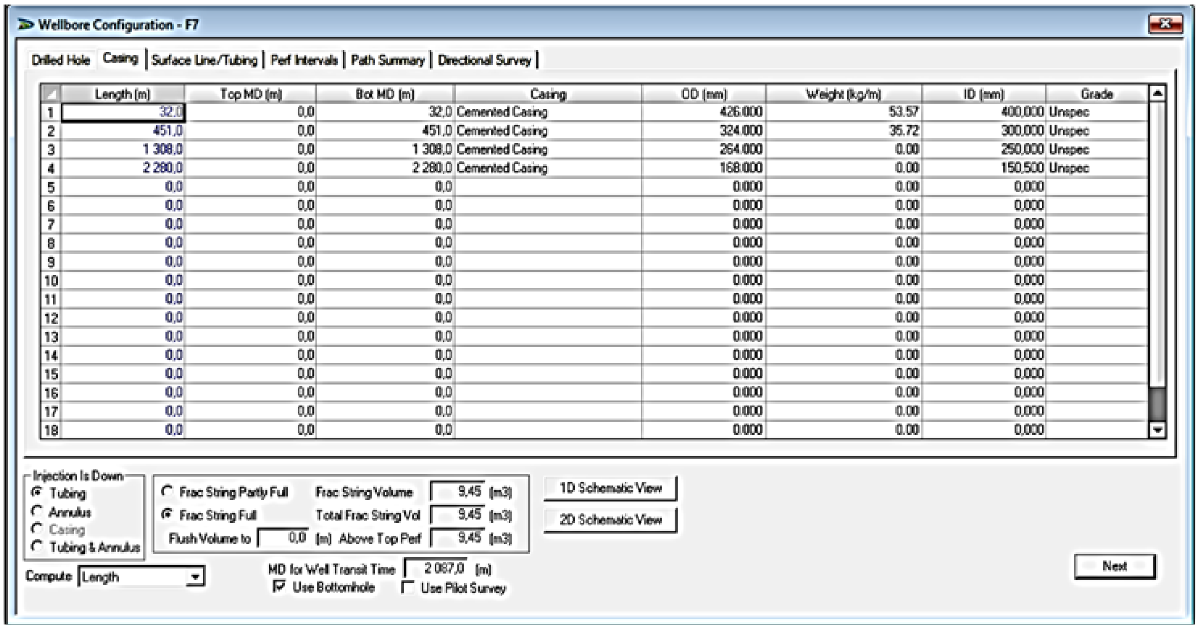


Figure 5 – Casing

The term "casing tab" refers to the description of the casing, which may or may not include the complete pipe string used for transporting treatment fluids. The initial value for the top MD entry of segment number one is set to zero by default. The user is required to provide the outer diameter (OD) and inner diameter (ID) for each segment. However, the weight and grade are optional fields.

1. 0–32 m (Conductor)
2. 0–451 m (Surface Casing)
3. 0–1308 m (Intermediate casing)
4. 0–2280 m (Production casing)

Will also add the diameter, the effective diameter, and the weight to get the diagram in 2D mode.

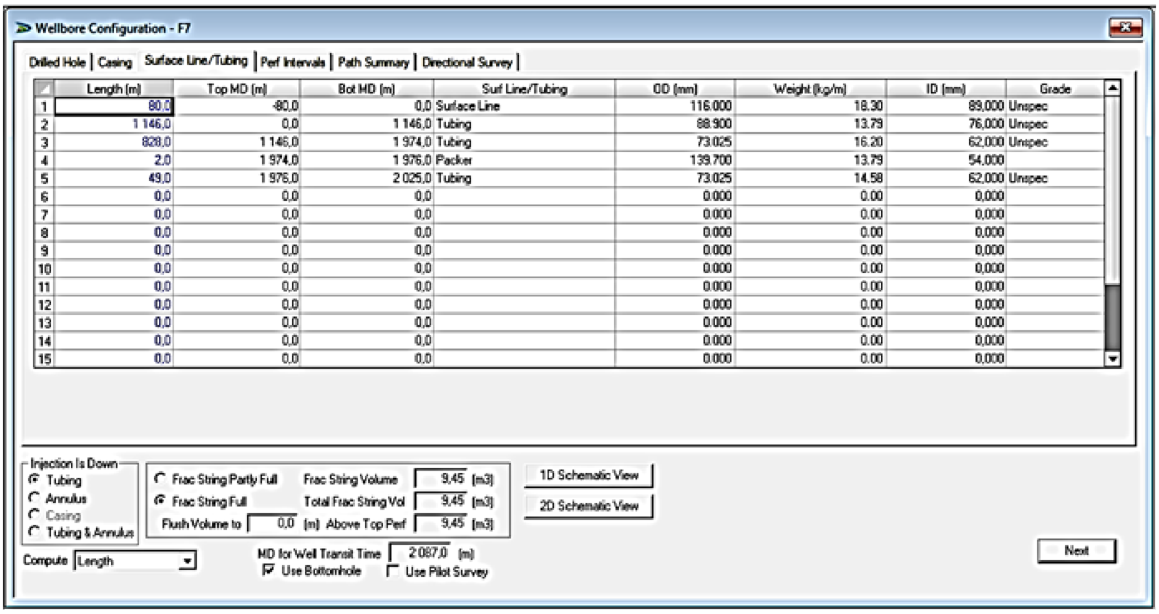


Figure 6 – Surface line/Tubing

The Surface Line/Tubing tab provides a description of the surface line and tubing. The Surface Line/Tubing tab is utilized to specify the surface line and tubing arrangements. Like other parts, this tab enables the input of personalized data. A crucial factor to take into account is the installation of the packer. If a packer is not installed when injecting fluid into the reservoir, the fluid will reset upwards, so preventing the formation of a fracture.

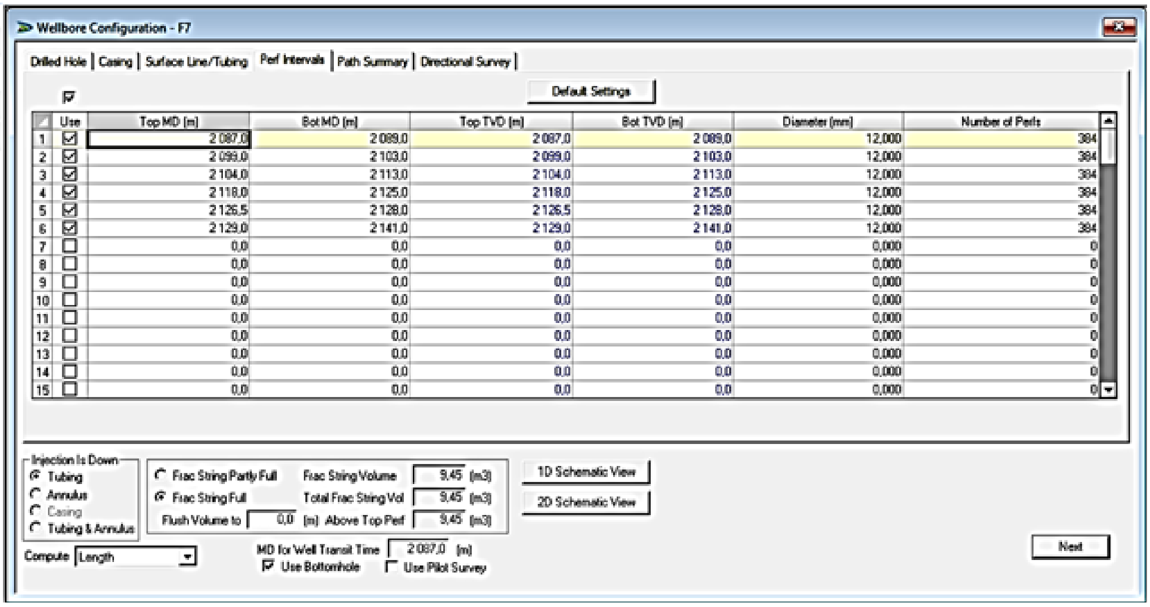


Figure 7 – Perforations interval

There are three methods available for representing multiple perforated intervals. Here are some general guidelines for when to employ each of these three distinct strategies:

When there are several zones that are quite close to each other compared to the total height of the hydraulic fracture, and you expect significant overlap between many fractures, it is often more effective to represent them as a single perforated interval in the model. To consider the interference between these many hydraulic fractures, you can modify the Opening Factor.

Fracture Design mode allows for the simulation of only one hydraulic fracture at a time, namely one perforation set. Conversely, in Fracture Analysis mode, it is possible to simulate several hydraulic fractures simultaneously, including various sets of perforations.

For every perforated interval, the system automatically scans the interval to identify the zone with the lowest stress and designates the center of that zone as the initial hydraulic fracture depth.

Thus, it is not mandatory for us to input the exact overall perforated height, nor is it always desirable for you to do so. Instead, it is advisable to input the perforation information in a manner that ensures the hydraulic fracture start in the simulator occurs precisely at the desired site. We also have 6 perforation zones. The total capacity is 36.5 m.

The screen is the interface where you input the required parameters to simulate the time-temperature history of the fluids in the wellbore.

Surface Fluid Temperature refers to the temperature of the fluid that enters the wellbore at the surface, specifically the temperature of the fluid in the tank. This refers to the initial temperature of the fluid before the introduction of carbon dioxide or nitrogen in a foam treatment simulation.

Surface Proppant Temperature refers to the initial temperature of the proppant prior to its injection into the wellbore.

Surface N2 Temperature: This refers to the initial temperature of the nitrogen before it is introduced into the primary fluid-proppant mixture.

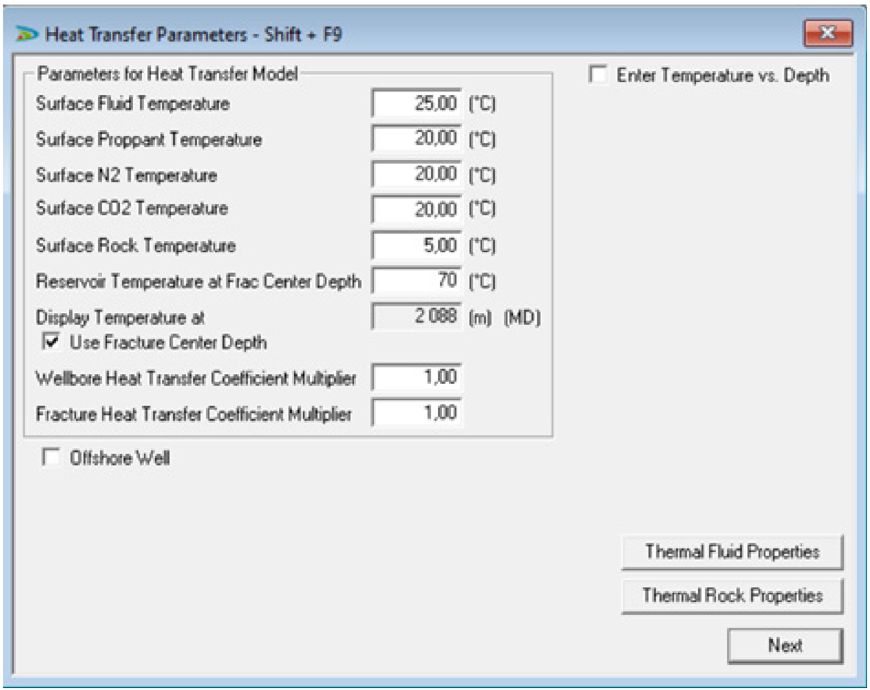


Figure 8 – Heat Transfer Parameters

Surface CO2 Temperature refers to the temperature of carbon dioxide prior to its introduction into the primary fluid-proppant mixture.

Surface Rock Temperature refers to the temperature of the Earth's surface or in its immediate vicinity. While the exact value of this number is not commonly understood, even significant deviations in it have only negligible effects on forecasts of wellbore heat transmission.

Temperature at the center depth of the hydraulic fracture in the reservoir: This represents the temperature of the reservoir at the midpoint of the perforation depth. Furthermore, this value is employed not only for heat transfer calculations but also for the purpose of selecting the appropriate rheology data from the Fluid Library.

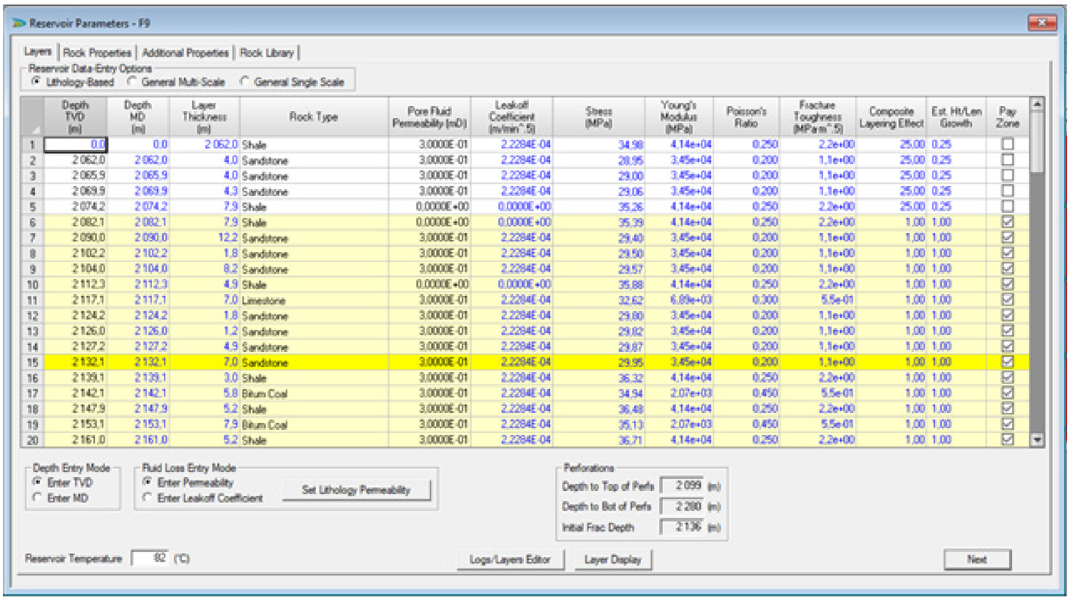


Figure 9 – Reservoir Parameters

This section is crucial as it allows us to input essential geological and mechanical parameters. Here, we define rock types, pore fluid leak-off coefficients, Young's modulus, and other relevant properties. Additionally, we select the pay zones where the fluid will interact with the rock formations. These inputs are vital for accurate modeling and simulation, ensuring that the program reflects the real-world conditions of the reservoir.

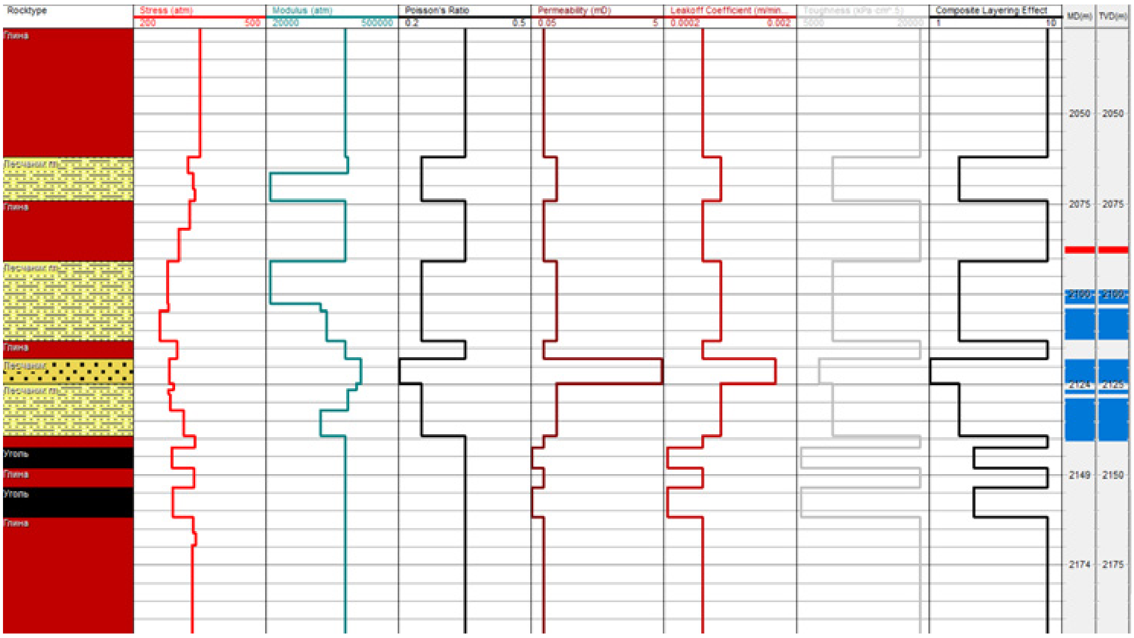
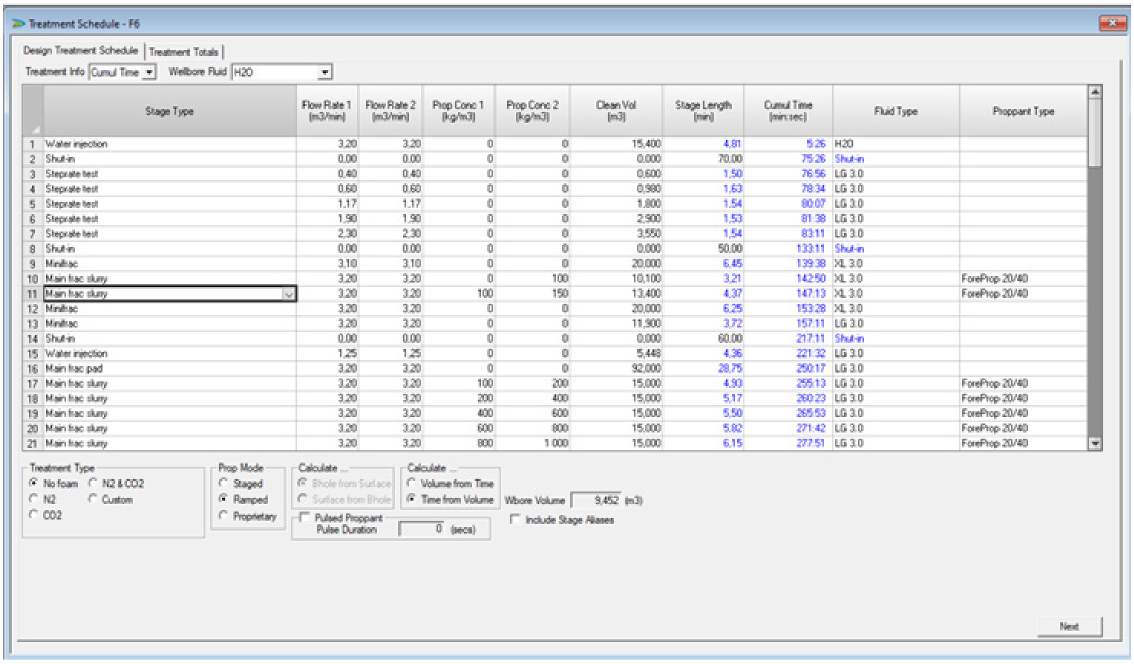


Figure 10 – Graph view our Rock Type



	Stage Type	Flow Rate 1 (m3/min)	Flow Rate 2 (m3/min)	Prop Conc 1 (kg/m3)	Prop Conc 2 (kg/m3)	Clean Vol (m3)	Stage Length (min)	Cumul Time (min:sec)	Fluid Type	Proppant Type
1	Water injection	3,20	3,20	0	0	15,400	4,81	5:26	H2O	
2	Shut-in	0,00	0,00	0	0	0,000	70,00	75:26	Shut-in	
3	Stepxate test	0,40	0,40	0	0	0,600	1,50	76:56	LG 3.0	
4	Stepxate test	0,60	0,60	0	0	0,980	1,63	78:34	LG 3.0	
5	Stepxate test	1,17	1,17	0	0	1,800	1,54	80:07	LG 3.0	
6	Stepxate test	1,90	1,90	0	0	2,900	1,53	81:38	LG 3.0	
7	Stepxate test	2,30	2,30	0	0	3,550	1,54	83:11	LG 3.0	
8	Shut-in	0,00	0,00	0	0	0,000	50,00	133:11	Shut-in	
9	Minifrac	3,10	3,10	0	0	20,000	6,45	139:38	XL 3.0	
10	Main frac slurry	3,20	3,20	0	100	10,100	3,21	142:50	XL 3.0	ForeProp 20/40
11	Main frac slurry	3,20	3,20	100	150	13,400	4,37	147:13	XL 3.0	ForeProp 20/40
12	Minifrac	3,20	3,20	0	0	20,000	6,25	153:28	XL 3.0	
13	Minifrac	3,20	3,20	0	0	11,900	3,72	157:11	LG 3.0	
14	Shut-in	0,00	0,00	0	0	0,000	60,00	217:11	Shut-in	
15	Water injection	1,25	1,25	0	0	5,448	4,36	221:32	LG 3.0	
16	Main frac pad	3,20	3,20	0	0	92,000	28,75	250:17	LG 3.0	
17	Main frac slurry	3,20	3,20	100	200	15,000	4,93	255:13	LG 3.0	ForeProp 20/40
18	Main frac slurry	3,20	3,20	200	400	15,000	5,17	260:23	LG 3.0	ForeProp 20/40
19	Main frac slurry	3,20	3,20	400	600	15,000	5,50	265:53	LG 3.0	ForeProp 20/40
20	Main frac slurry	3,20	3,20	600	800	15,000	5,82	271:42	LG 3.0	ForeProp 20/40
21	Main frac slurry	3,20	3,20	800	1 000	15,000	6,15	277:51	LG 3.0	ForeProp 20/40

Figure 11 – Treatment schedule

In this part, they add the proppants and the type of fluid they are pumping. Also, here add a mini hydraulic fracturing with the main hydraulic fracturing to achieve the desired result. As a proppant, took both HiWAY ForeProp 20/40 technology. LG 3.0 linear gel was used as a liquid. LG 3.0 gel is very similar in properties to crosslinked gel YF130.

The schedule included 61 tons of proppant, 282.5 m3 of YF130 liquid, a sequential increase in the concentration of proppant from 100 kg/m3 to 1100 kg/m3 and a liquid flow rate of 3.2 m3/min.

The main conclusions from mini hydraulic fracturing:

- The reservoir pressure in the downhole zone is between 140 and 155 atm, according to the volume of liquid used to fill the well (~2.5 m3) and the examination of the pressure drop curve following the tests.
- Based on the mini-HF results, the liquid's efficiency is approximately 28–30%.

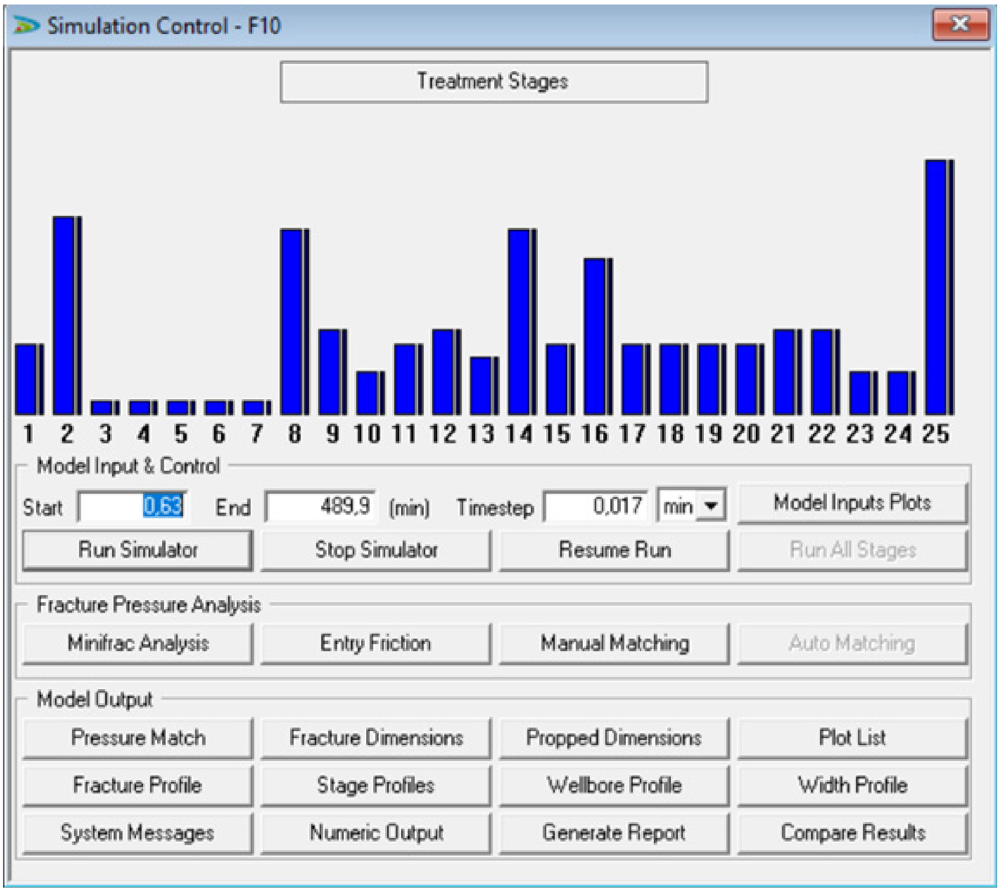


Figure 12 – Simulation Control

Once all the data is entered, proceed to the next stage. The blue graphs represent the stages of hydraulic fracturing process. As progress step by step, these graphs will change color, indicating a correct hydraulic fracturing schedule. By pressing the "Run" button, can view the results of work, providing a clear overview of the fracturing process and its effectiveness.

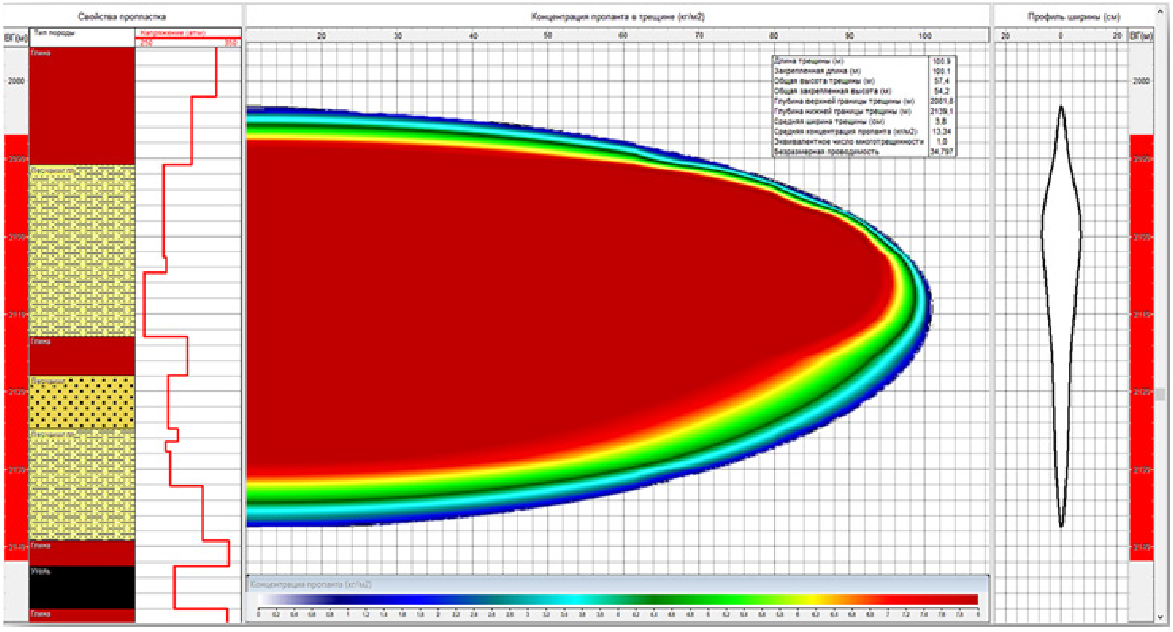


Figure 13 – FracPro Results

As illustrated in the figure, our simulation indicates that the fracture length is 100.9 meters and the width is 3.8 centimeters, both of which correspond to our calculations. Additionally, the concentration of proppant is displayed, providing further insight into its distribution within the fracture.

Table 7 – Results of FracPro

Fracture Length	100.9 m
Propped Length	100.1 m
Total Fracture Height	57.4 m
Total Propped Height	54.2 m
Fracture Top Depth	2081.8 m
Fracture Bottom Depth	2139.1 m
Average Fracture Width	3.8 cm
Average Proppant Concentration	13.34 kg/m^2
Dimensionless Conductivity	34.797

The results from the FracPro software are shown below.

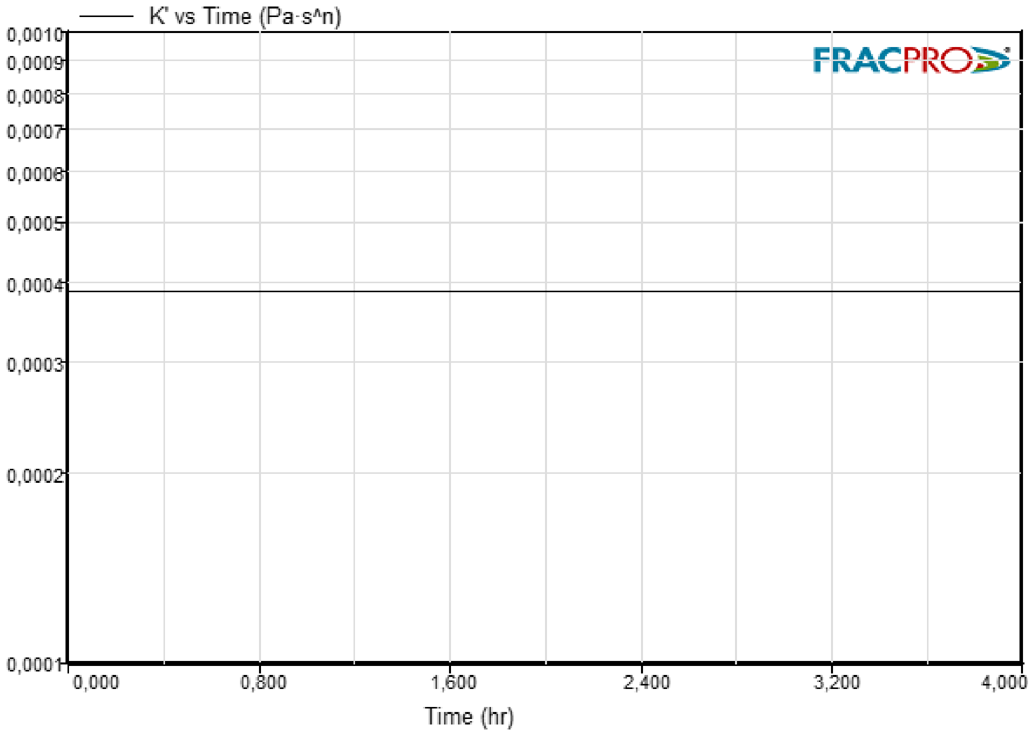


Figure 14 – K vs Time

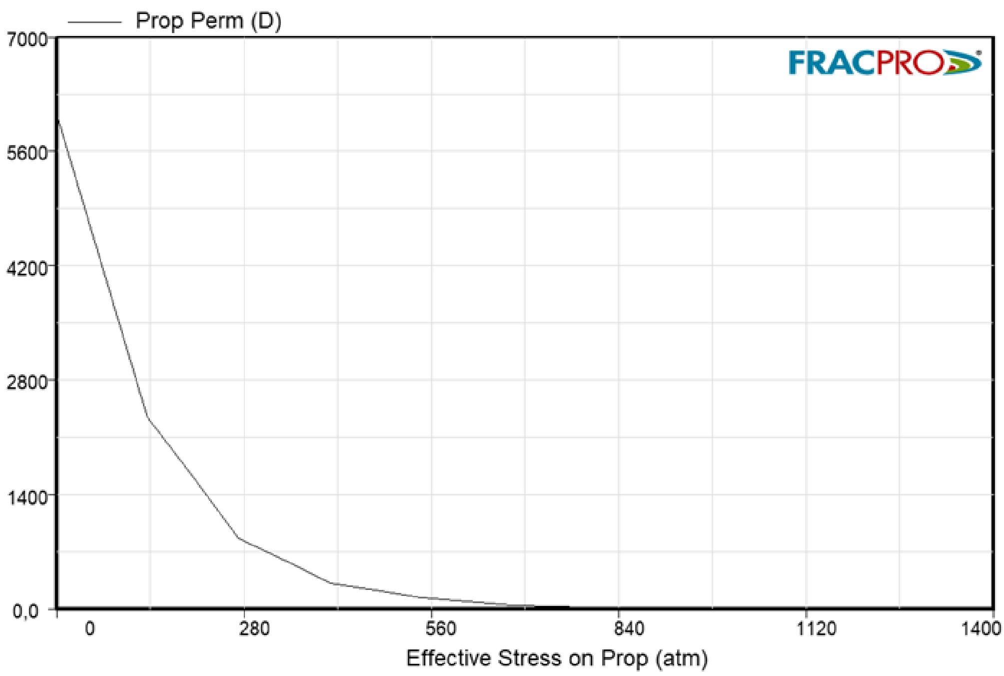


Figure 15 – Proppant Permebility vs Effective Stress

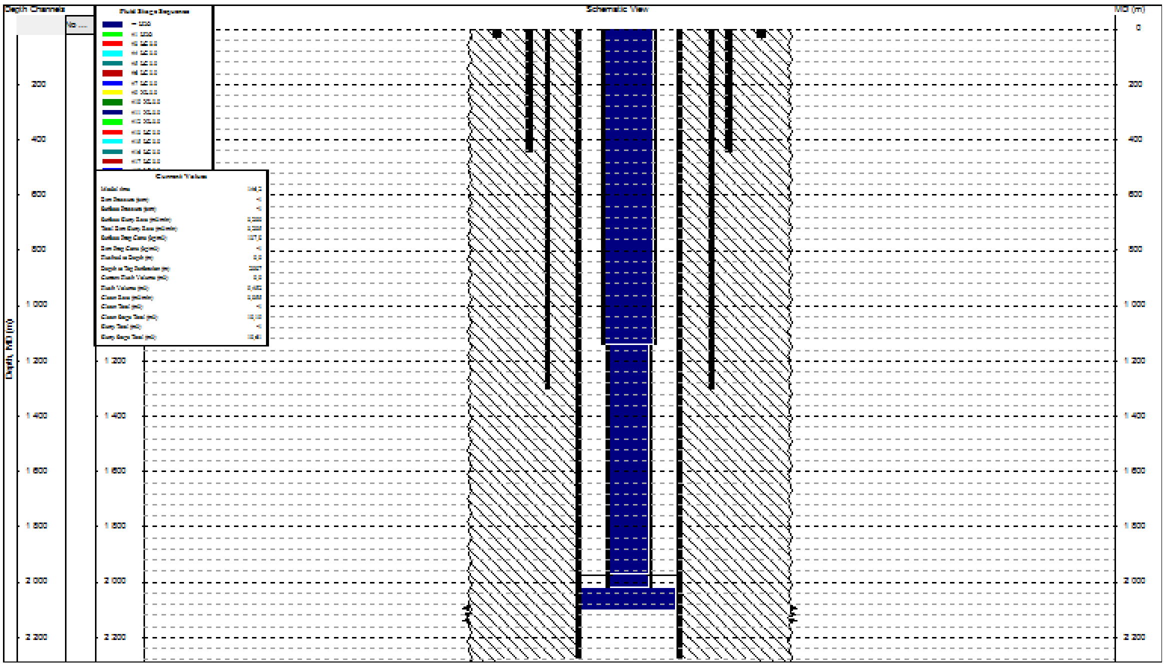


Figure 16 – 2D Schematic view

Overall, FracPro is a versatile and powerful tool that plays a critical role in the success of hydraulic fracturing operations. Its advanced capabilities for design, simulation, modeling, analysis, and optimization empower engineers to make informed decisions and achieve superior results in unconventional reservoir development.

Conclusion

The HiWAY hydraulic fracturing technique has proven to be superior in enhancing reservoir productivity at Field X. Its innovative approach to creating open channels within fractures results in improved fluid conductivity and hydrocarbon flow, leading to better economic outcomes. This study provides valuable insights for industry practitioners, enabling informed decisions regarding the adoption and implementation of advanced hydraulic fracturing methods.

REFERENCES

1 Jenhings A.R. Enhanced Well Stimulation, 2018.
2 Belyadi H., Fathi E. Hydraulic Fracturing in Unconventional Reservoirs, 2004.
3 Kislik P. Intensification of Inflow, 2007.
4 Messaoud H. Performance Analysis of Hydraulic Fracturing Technique and HIWAY Flow Channel Fracturing. Araboil Natural Gas, 2022.
5 Ning X., Wang B., Feng Y. Numerical Simulation of Channel Fracturing Technology in Developing Shale Gas Reservoirs. ScienceDirect, 2020.
6 Sharif A.M., Nagalakshmi, NVR. Advance Technique to Increase Production from Tight Formations Using HiWAY Flow-Channel Hydraulic Fracturing Technique, 2022.
7 SLB Library. HiWay Flow-Channel Fracturing Technique, 2018.
8 Sharif A.M. Advance Technique to Increase Production from Tight Formations Using HiWAY Flow-Channel Hydraulic Fracturing Technique, 2017.
9 Zhao M. Dynamic Cross-Linking Mechanism of Acid Gel Fracturing Fluid, 2020.

[1]*Жақсылықов Ж.
Мұнай және газ өндіру операторы, ORCID ID: 0009-0005-8120-7621,
*e-mail: z_zhaksylykov@kbtu.kz
[1]Саматов А.
Мұнай және газ өндіру операторы, ORCID ID: 0009-0006-1238-2386,
e-mail: a_samatov@kbtu.kz
[2]Шарипов Ж.
Геология және кен орындарын игеру департаментінің директоры директоры,
ORCID ID: 0000-0002-5994-7421

[1]"QazaqGaz барлау және өндіру" ЖШС, Тараз қ., Қазақстан
[2]"QazaqGaz ғылыми-техникалық орталығы" ЖШС, Астана қ., Қазақстан

АМАНГЕЛДІ КЕН ОРНЫНДА HIWAY ГИДРАВЛИКАЛЫҚ ЖАРУ ӘДІСІН ҚОЛДАНА ОТЫРЫП ҚАБАТТЫҢ ӨНІМДІЛІГІН АРТТЫРУ

Аңдатпа

Бұл зерттеу Амангелді кен орнындағы қабат өнімділігін арттыру үшін гидравликалық жару әдістерін қолдануға арналған. Нақтырақ айтқанда, зерттеу көмірсутектерді өндіруді оңтайландыру мақсатында пропант орналастырудың жетілдірілген HIWAY әдісіне назар аударады. Әдістің негізгі параметрлерін бағалау үшін математикалық модельдер әзірленіп, FracPro бағдарламалық құралын қолдану арқылы модельдеу және талдау жүргізілді. Дереккөздер ретінде OnePetro және ScienceDirect сияқты жалпыға қолжетімді платформалар пайдаланылды, бұл ағымдағы тәжірибелер мен инновацияларға толық шолу жасауға мүмкіндік берді. Қосымша ақпарат дуалды оқыту барысында жиналды, бұл зерттеуді практикалық мәліметтермен байытып, үлгілерді нақты дала жағдайларына сәйкестендіруге мүмкіндік берді. Зерттеудің теориялық және эмпирикалық тәсілдерін біріктіру ғылыми журналдарда жарияланған материалдар арқылы жүзеге асты. Алынған нәтижелер HIWAY әдісінің тиімділігін арттыру, пайдалану шығындарын төмендету және қоршаған ортаға әсерді азайту әлеуетін көрсетті. Бұл зерттеу су қоймаларын басқару саласында озық модельдеу әдістерін практикалық тәжірибемен ұштастырудың маңыздылығын айқындайды.

Тірек сөздер: гидравликалық жару, HiWAY әдісі, Амангелді кен орны, FracPro бағдарламалық жасақтамасы.

[1]*Жаксылыков Ж.,
оператор по добыче нефти и газа, ORCID ID: 0009-0005-8120-7621,
*e-mail: z_zhaksylykov@kbtu.kz
[1]Саматов А.,
оператор по добыче нефти и газа, ORCID ID: 0009-0006-1238-2386,
e-mail: a_samatov@kbtu.kz
[2]Шарипов Ж.,
директор департамента геологии и разработки месторождения,
ORCID ID: 0000-0002-5994-7421

[1]ТОО «Разведка и Добыча QazaqGaz», г. Тараз, Казахстан
[2]ТОО «QazaqGaz Научно-технический центр», г. Астана, Казахстан

ПОВЫШЕНИЕ ПРОДУКТИВНОСТИ ПЛАСТА С ИСПОЛЬЗОВАНИЕМ МЕТОДА ГИДРОРАЗРЫВА ПЛАСТА HIWAY НА МЕСТОРОЖДЕНИИ АМАНГЕЛЬДЫ

Аннотация

В этом проекте изучается применение методов гидроразрыва пласта для повышения производительности коллектора на месторождении Амангельды. Исследование было сосредоточено на передовом методе HIWAY, который оптимизирует размещение проппанта для улучшения извлечения углеводородов. Математические модели были разработаны для оценки ключевых параметров этого метода и реализованы с использованием программного обеспечения FracPro, что позволяет проводить детальное моделирование и анализ. Данные для этого исследования были собраны из общедоступных источников, включая OnePetro и ScienceDirect, что обеспечивает всесторонний обзор текущих практик и инноваций. Дополнительная информация была получена во время дуального обучения на месторождении Амангельды, что дало практические знания и сопоставило модели с условиями, характерными для месторождения. Вклады научных журналов еще больше обогатили исследование, поддержав интеграцию теоретических и эмпирических подходов. Результаты подчеркивают потенциал метода HIWAY для максимизации эффективности, снижения эксплуатационных расходов и смягчения воздействия на окружающую среду. Этот проект подчеркивает важность объединения передового моделирования с практическим опытом работы на местах для решения проблем в управлении коллектором.

Ключевые слова: гидроразрыв пласта, метод HiWAY, месторождение Амангельды, программное обеспечение FracPro.

Article submission date: 24.06.2024