VNU Journal of Science : Earth and Environmental Sciences, Vol. 31, No. 1 (2015) 49-66

Effects of Water Invasion to Design and Production Procedure in Fractured Basement Reservoir, SuTu Den oil Field and Prevention Solutions

Trần Văn Xuân*

Hồ Chí Minh City, University of Technology, 268 Lý Thường Kiệt, district 10, Hồ Chí Minh city

Received 15 January 2015
Revised 09 February 2015; Accepted 20 March 2015

Abstract: During oil and gas production processes, especially in fractured basement reservoir those related to formation water, the ability of water invasion is quite possible. Based on realistic production and injection activities at SuTuDen oil field, CuuLong Basin, Vietnam, the author researched, evaluated the effects of formation water to oil and gas bearing fractured basement reservoir which each exploration, appraisal, development and production stage accordingly, determined the solution, appropriate technology to attain the targets. In exploration stage, early detected the connate water appearance would guide to discover the petroleum accumulation or avoid drill the dry holes, determine the initial oil water contact which serving for appraisal well design as well could be the foundation to estimate the hydrocarbon initial in place. In development, production stages, in the case particularly methods applied, such as well observing, reservoir monitoring, formation testing, production technology diagram updating and revising, water invasion possibility, level predicting to reservoir, since then build up the theories in order to propose the instant solutions (reducing flow rate, adjusting production –water injection regime, isolating potential water influx) as well as long term solutions (monitoring pressure behavior of production well closely, optimizing production-injection design, determining and quantifying the origins of production water) to prevent and protect water invasion hence increasing oil recovery efficiency.

Keywords: Fractured basement reservoir, formation water, production and injection, MPLT, DST, hydrodynamic model, BS & W, EOR.

1. Introduction

The SD SouthWest basement reservoir has discovered in October 8, 2000 by wildcat well SD-1X. It is the largest and the main producing reservoir of SuTuDen & SuTuVang complex which located on block 15-1, Cuu Long basin (figure 1, 2). With the fact that oil and gas production in fractured basement reservoir of STD oil field, CuuLong Basin Vietnam has been showed out, in all cases there is very high possibility of formation water invaded.

The main problem in exploration and production is besides reusing the energy of aquifer (especially in primary recovery) but also try to minimize the worse effects to production

* Corresponding author. Tel.: 84-903700770.
Email: tvxuan@hcmut.edu.vn

processes. Depend on specific stages of field development, every ones who involve to reservoir management, production operation need to apply appropriate methods, technology in order to reach the planned targets.

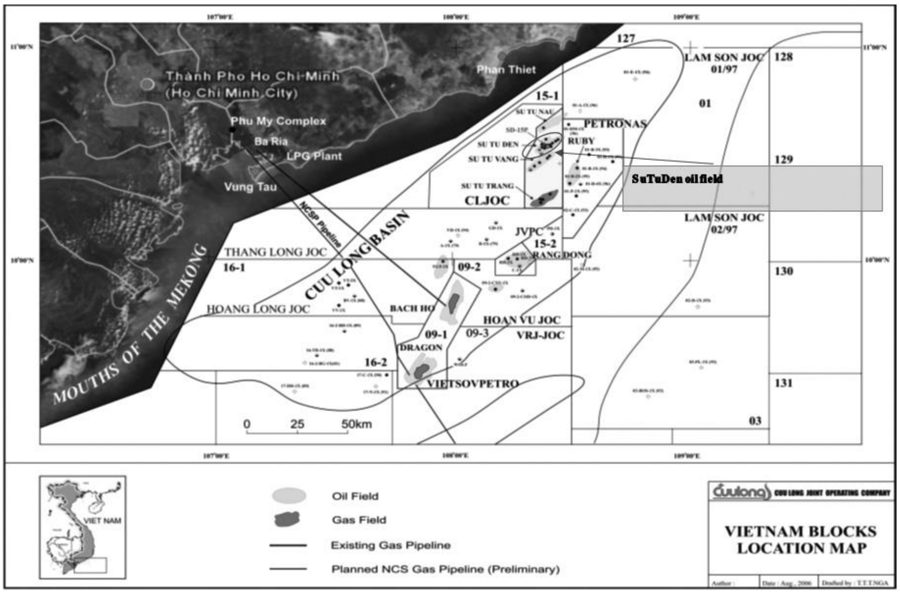

Figure 1. Location of SD and SV complex .

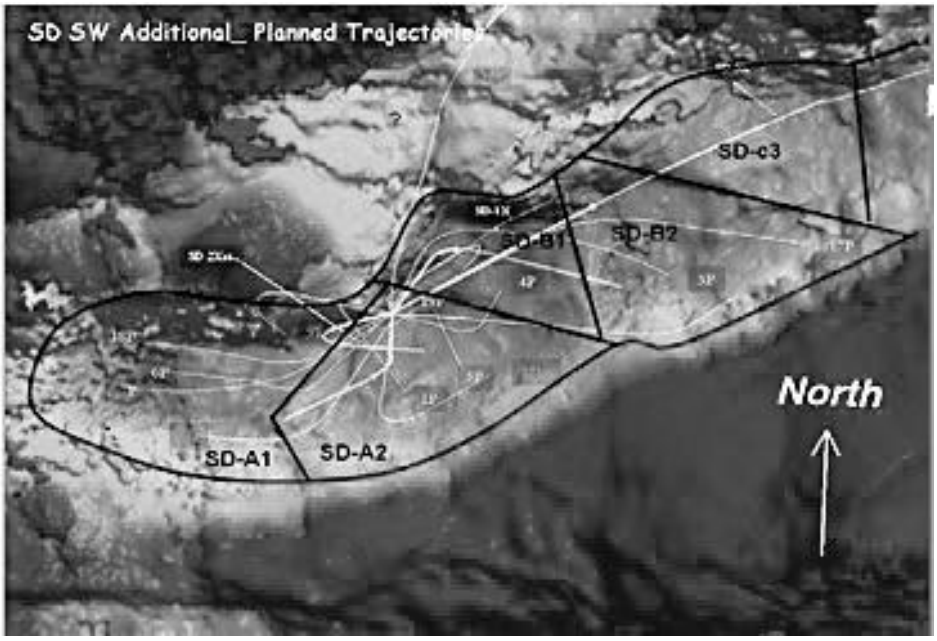

Figure 2. Structure of SD SW basement reservoir.

2. General of formation water in SD oil field

2.1. Characteristics of formation water

The computational results have illustrated that formation water is the dominant water contributes to produced water; hence, it is essential to inquire further research into its nature and origin. The data computation by linear mixing model has also given an optimized chemical profile of water source and it is assigned at formation water. The calculated chemical profile allows characterizing its nature and understanding more about the origin of formation water.

Previous studies on hydrocarbon in basement rocks in Cuulong basin have concluded that most basement oil is originated and formed in continental environments. Before Oligocene-Miocene subsidence time, the basement reservoir was once exposed to the surface, in which filled water may come from sources such as ground water, lakes, lagoons, marshes and so on. Water contribute to aquifers during this time would be meteoric water or mixtures of meteoric water and saline or brackish water of coastal environment (table 1).

Calculated formation water has its chloride contents as low as 1,878 mg/l and total dissolved solids (TDS) of about 3.4 g/l; this range is similar to characteristics of fresh brackish water. This allows suggesting that water contributes to basement reservoir is an ancient aquifer which was buried during Oligocene-Miocene subsidence time; the aquifer might originally contain mixtures of meteoric water and seawater [1].

Preliminary remarks have suggested that SD-2K water sample collected from SD-2K well during production may be most favorably considered to be representative of formation water in the fractured basement reservoir. However, the **water** sample may have been contaminated with drilling mud loss during the first development drilling campaign of SD-1K÷SD-7K wells. The linear mixing model computation have given the result of approximate 3% brines contaminated in SD-2K water sample.

This result turns out to be another approach to estimate concentrations of other components in formation water by subtracting their contaminated quantities from SD-2K water sample.

Table 1. Chemical profile of formation water by optimized computation

	Chloride (mg/l)	Bromide (mg/l)	Sulfate (mg/l)	Sodium (mg/l)	Total Ions (meq/l)	TDS (g/l)
SD-2K	6,458	2.16	69.13	4,004.13	367.40	10.80
Brine	154,560	69.25	1,856.00	96,221.00	8,792.60	259.07
Well 1K	3,465	5.20	209.00	1,451.00	313.30	6.13
Formation Water	**1,878**	**0.09**	**13.87**	**13.87**	**106.78**	**3.40**

Table 2. Potassium, Calcium, Magnesium concentration in formation water

	Potassium (mg/l)	Calcium (mg/l)	Magnesium (mg/l)
SD-2K	165.32	30.60	39.51
Brine	1,868.00	1,104.00	1,281.00
Well 1K	306.00	616.00	9.12
Formation Water	112.70	N/A	1.11

The estimated concentrations of some cations by subtraction of contaminants in formation water are given in table 2; Potassium and Magnesium concentrations are proved to be reasonably estimated, but Calcium concentration is estimated negative due to its surprising low level in SD-2K water sample. Water in buried aquifer usually has Calcium concentration much higher than its own Magnesium concentration; Calcium and Magnesium have the same range only in deep buried depth. If it is the case, SD-2K water, and then formation water, may flow up from deeper depth of basement reservoir; however, only one water sample of SD-2K is not representative enough to draw any conclusion.

The other water samples, which can be considered to be approaching to formation water in basement reservoir, are some produced water samples taken in production well 1K. These water samples have most solute chemical components with about half quantities of those in SD-2K water sample, and these are the poorest solute content among all produced water samples, however, they still have Calcium concentration higher than in SD-2K water sample. It is still interesting question on unknown reason of lacking Calcium in SD-2K water sample.

Despite original composition before burying, formation is expected to have very little quantities of Magnesium and Sulfate due to water-rock interaction [2]. The rather high concentration of Sulfate in produced water of well 1K indicate that it also contains a significant amount of injected water or drilling fluid, so calculated chemical profile of formation water would be containing chemical components of significantly lower quantities than that of 1K produced water sample [1].

This is the fact that validates appropriateness of the optimized chemical profile of formation water. In conclusion, the optimized chemical profile of formation water is in good agreement with geological settings and paleo-environment of Cuulong basin, it is also appropriate to observation chemical data of produced water.

2.2. General contribution of water sources to produced water

Data computational results have proved all formation water, injection water and mudlosses were present in produced water; however, their proportions were timely dependent and varied from well to well. The computed proportions of water sources to produced water are plotted figure 3, solid lines are moving averaged by time.

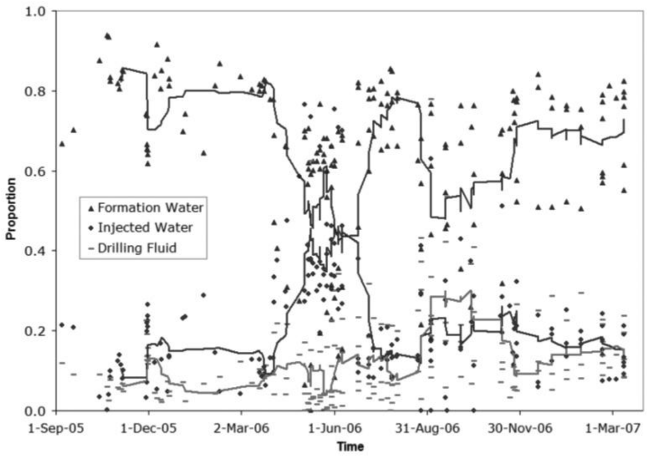

Figure 3. General contribution of water sources to produced water.

Generally, about two thirds or more proportion (figure 3 and table 3) of produced water is derived from formation water during acquisition time of water samples using in this study. It is likely expected that formation water would contribute with a greater proportion to the volume of reservoir water body.

Before April 2006, produced water in almost all area (MPA and SD-6K/7K/18K) was dominantly contributed from formation water with ratio of around 75% or higher. Injected water contribution reached its high magnitude during May and Jun 2006, then dropped and increased slightly again, and have had a trend of decreasing recently (till March-2007). These behaviors of injected water, of course, always accompanied with the change of formation water contribution but in opposite direction. All these described water dynamics would be related to water injection performance of SD field in previous time (figure 4).

The sharp increase of injected water contribution to produced water from April to July 2006, and then dropped immediately after that, was agreeably associated with the intensive injection time from July to December 2005 and the later shut-in and drops of water injection (figure 4). April 2006 was also the time that almost tracers started to be observed simultaneously and regularly in production wells. This indicates an average time of around 8 months for water movement from injector to producer, quite accordance with data records by tracer movements (table 3).

The highest contribution of injected water to produced water occurred in well 4K located in the center of MPA. Well pressure interference observation also shown that WHFP (Well Head Flowing Pressure) on well 4K immediately stopped decreasing and was stabilized as a result of water injection restart on 12 December 2005 in wells 2I, which is the most intensive injection, its WHFP was also dropped sharply when water injection in wells 12I and 2I were shut down and increased when water injection on these two wells was back online during 6-9 September 2006. However, well 4K received tracer from well 2I and 9I during January to October 2006, indicating that 4K produced water was supported directly from these two injectors.

The greatest contribution of formation water to produced water was observed in well 1K, where injected water was the lowest one. This lowest contribution of injected water is agreeable with tracer movement observation - no tracer was detected during production time in well 1K [3].

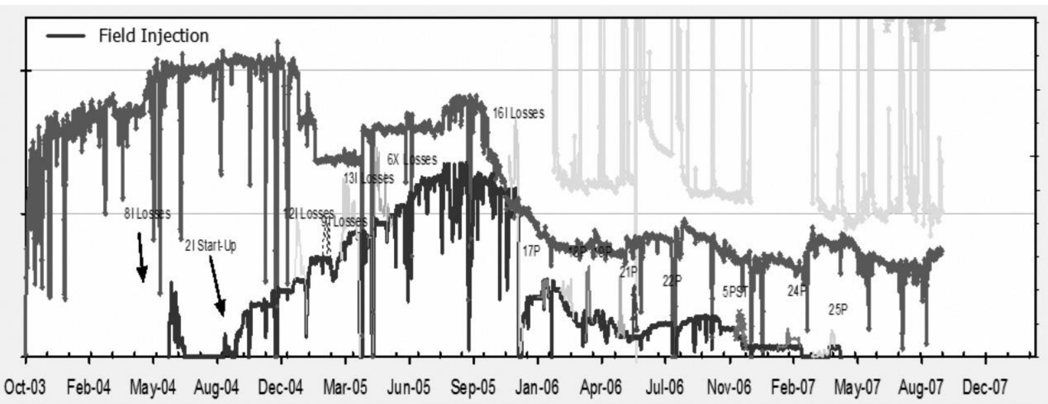

Figure 4. Total injection performance in SD field.

Table 3. Tracer movement observation and its duration

Date\Well	3K	4K	5K	6K	6Kst	7K	17K	18K	16I
7-Sep-05			184				Maker 2I 8I	9Ist 1	2Ist 13Ist
20-Sep-05			197						
28-Oct-05									235
29-Oct-05									235
24-Jan-06		323							
8-Feb-06						218			
25-Feb-06				234					
1-Apr-06								270	
3-Apr-06	392						392/271(?)		
6-Apr-06		395/274					396/274(?)	275	
10-Apr-06	399	399/278							
14-Apr-06	403								
16-Apr-06	404							285	
18-Apr-06	405								
19-Apr-06	407							288	
26-Apr-06	409								
28-Apr-06	415								
1-May-06	417	417/296							
3-May-06	420								
7-May-06	422	417/301							
9-May-06	426								
11-May-06		417/307				308			
15-May-06	430								
18-May-06	434	434							
19-May-06		437						318	
29-May-06		444							
1-Jun-06	448	448			331			331	
5-Jun-06		451						335	
9-Jun-06		455						339	
25-Jun-06		459						355	
5-Jun-06		475			364		485	485/365	
10-Jun-06					369			490/370	
17-Jun-06	490				376			497/377	
23-Jun-06					382			503/383	
28-Jun-06					387/388			508/388	
2-Aug-06					392/393			513/393	
22-Aug-06					412/413			533/413	
4-Sep-06		546/425			425			546/426	
18-Sep-06		560/439			439/440			560/440	
3-Oct-06		575/454			454/455			575/455	
16-Oct-06		588/467			467/468			588/468	

Two areas, which have weak communication, SW: 7K/18K and NE: 17K has received the greatest contribution of mudlosses in proportions of produced water.

Wells 16I and 4K also had significant proportion of drilling fluid in produced water; it is likely a result from hydro-dynamical communication with other wells in SD field.

In conclusion, magnitudes of calculated water source contribution to produced water in SD field correspond with injection and production data. Their behaviors are also confirmed by tracer movement observations both in spatial movements and moving durations. The contribution proportions of water sources to produced water, which were highly time dependent and varied spatially, indicated that their water amounts are only mixing in limited volumes or mixing locally in other words.

2.3. Anomalies in 7K produced water samples

It can be reminded that there are some outlier points that are not enclosed by the triangle of three end-members: injected water, drilling fluid and formation water [3]; these are the representative points for some 7K produced water samples. These are really anomalies that cannot be expressed by the linear mixing model; and they need be examined in details. Chemical compositions of these 7K produced water samples are given in table 4.

All 7K produced water samples have very high total dissolved solids which are equal to or higher than that of seawater while their Bromide contents are lower than. SD-7K-1 water sample also has Sulfate content as high as that of seawater while other soluble components are much higher than. It is noticeable that 7K produced water samples have pH lower than almost all produced water sample.

Table 4. Chemical compositions of 7K produced water samples

Sample Name	SD-7K-1	7K-bst-2	7K-bst-3	7K-bst-4
Acquisition Date	9-May-06	4-Sep-06	20-Sep-06	19-Feb-07
Total Dissolved Solids (g/l)	71.6	82.9	56.8	30.55
pH	6.9	6.9	6.8	7.1
Sodium Na^+ (mg/l)	24,367	30,089	20,214	9,463
Potassium K^+ (mg/l)	493	305	221	239.6
Magnesium Mg^{2+} (mg/l)	2,277	213	138	97.6
Calcium Ca^{2+} (mg/l)	1590	3372	2931	1,912.8
Chloride Cl^- (mg/l)	40,084	47,275	31,976	18,154
Bromide Br^- (mg/l)	91.8	61.6	37	40.39
Sulfate SO_4^{2-} (mg/l)	2,641	796	774	371.8
Bicarbonate (mg/l)	300	505	375	110
Total Ions (meq/l)	2,781.7	4,731.2	3,855.7	2,434.9

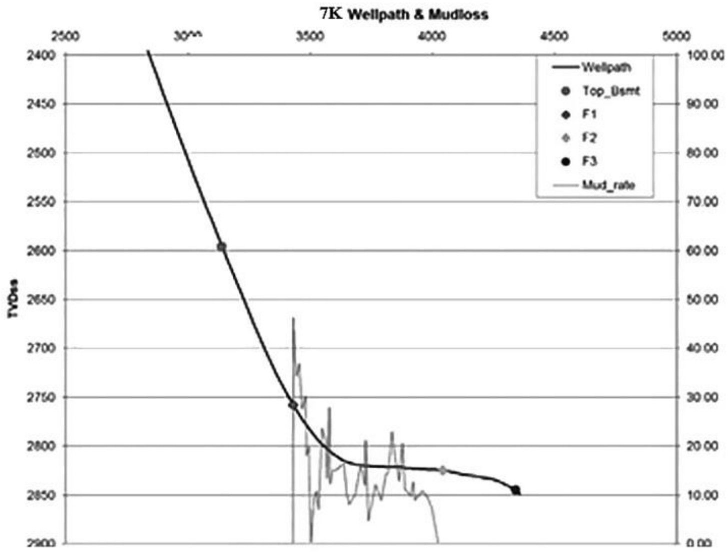

Figure 5. 7K Wellpath and Mudlosses.

The differences in chemical composition of some 7K produced water samples can be explained by the fact that these water samples were strongly affected by acid stimulation which were carried out because of weak pressure communication of well 7K, as well as drilling mud was lost mainly in horizontal wellpath of well 7K (figure 5). In addition, well 7K was also affected by mudlosses during the drilling course of well 18K in the same area.

The effects of water invasion not only depend on time and well location but also depended and varied which development stages of STD oil field.

3. In exploration and appraisal stages

Generally in this stage formation water is taken by special sampling or during DST (Drill Stem Test), due to time limitation those all most water sampler are invaded by drilling mud with very high TDS (table 5). The water analysis results will be applied to calculate & design the field technology system and anti-erosion, furthermore water contents are serving for reasonable drilling mud and cementing designing.

Table 5. Produced water (during DST) analysis results

Water sample	A-X	C-X	D-X	E-X	F-X
Salinity (mg/l)	137,000	209,000	248,35	n/a	23,000
Resistivity@ 25 degC (Ωm)	0.028	0.050	0.03	n/a	0.3
Viscosity @ 20 degC (Cst.)	27.58	3.15	3.5	n/a	n/a
Conductivity @ 25 degC (ms/cm)	354.240	198.90	249	n/a	33.5
Specific Gravity @ 20 degC (g/cc)	1.091	1.137	1.1626	n/a	1.0166
pH	5.1	6.1	6.55	n/a	7.5

4. In production stage

4.1. Well and reservoir monitoring

Integrated reservoir management requires close monitoring of the reservoir and well performance throughout the field life. This includes data gathering by constant surveillance and periodic testing of the reservoir. Constant surveillance includes recording production rates of all wells and bottomhole flowing pressures. The testing portion involves initial DST's, injection tests, routine well tests, fluid sample collection and analysis, production logging, long term pressure surveys, pressure gradients surveys, periodic pressure build-ups, and occasionally interference testing.

An active reservoir monitoring policy is applied in well site of SuTuDen South West. The policy implemented to date has resulted in an extremely high quality data set that has been instrumental in further understanding the reservoir performance and ultimately helping to maximize recovery factor.

4.2. Well test

Flow tests and pressure build-up have been and will continue to be conducted to determine well deliverability, initial reservoir pressure, temperature and flow capacity (kh). In addition, material balance calculations will be used to determine initial connected pore volume and hydrocarbon initial in place (HCIIP). Injection tests will also be conducted on injection wells for the purpose of determining well injection, connectivity to the producing area of the reservoir and optimizing the completion intervals for injection wells. Also, fluid samples will be gathered for analysis to determine PVT parameters.

Well testing will be carried out routinely to measure production rates of oil, gas, and water. A plot of well liquid rates tracking displayed in Figure 6. These measurements support to keep up with any changes in production performance.

Well stream fluid samples will be collected regularly to measure oil and gas specific gravity and basic sediment and water (BS&W). Analysis from these tests will be valuable in order to detecting changes on reservoir fluid conditions, such as water break-through (Figure 7).

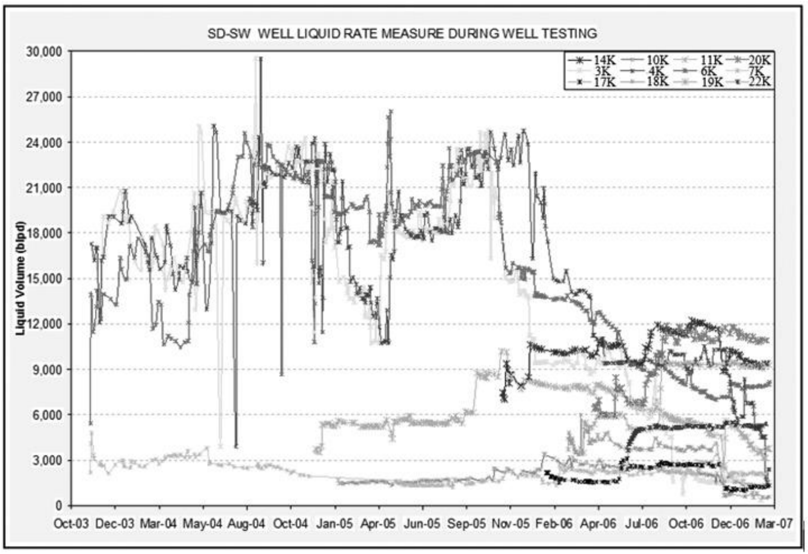

Figure 6. Well liquid rates measured routinely during well testing.

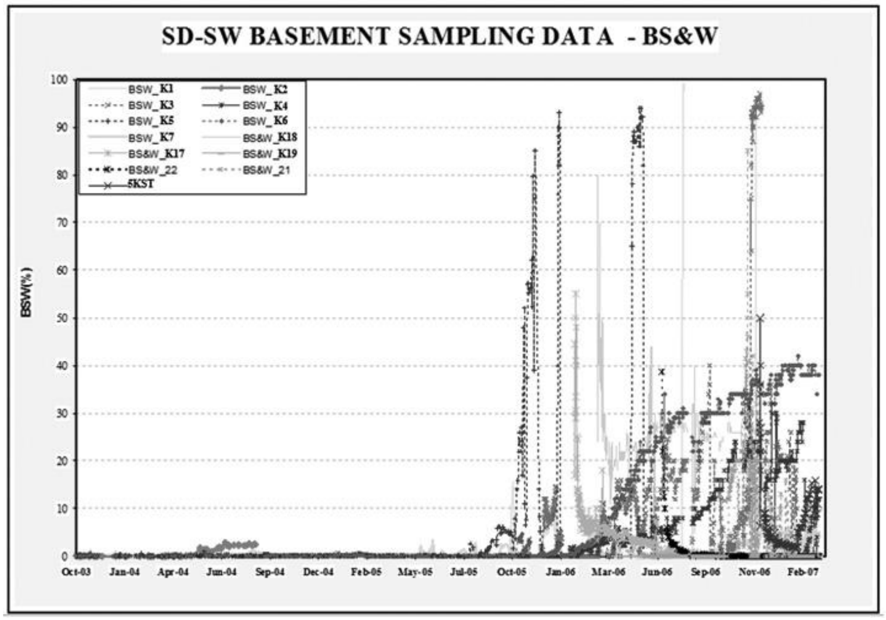

Figure 7. BS&W measurement by taking well stream fluid samples.

4.3. Well monitoring

Bottomhole pressure and temperature have been and will continue to be closely monitored in wells using permanent downhole gauges. One advantage of installing permanent gauges is the recording of reservoir pressure from pressure build-up data, especially during unplanned shut-in periods. In wells without permanent downhole gauges or where the gauge has failed, pressure and temperature surveys will be conducted every 6 months for the first two years of production, and annually thereafter. Besides, production logging tests (MPLT), corrosion surveys will be performed as needed for better understanding of downhole fluid entries and updating any changes.

As mentioned above, MPLT is one of important methods which support monitor well and reservoir performance. MPLTs have been conducted to date on SD-3K, SD-4K, SD-6K and SD-21K and workover opportunities have been generated using the collected data. The MPLT interpretation results provide valuable information for better understanding of downhole producing zones. Based on this data, further decisions to help maximize production such as acidizing, water shut-offs or even drilling sidetracks can be made with improved confidence. The results of the MPLT conducted on SD-6K in June 2006 are illustrated in figure 08. From this interpretation, it was decided to set a plug downhole to isolate water producing from below 2,927 mTVDSS. In this particular case the shut-off produced water zone was unsuccessful due to limitations of downhole isolation equipment but the value of the data is beyond dispute.

In summary, having a good understanding of the downhole performance through the results of MPLT work will improve production management and with the correct balance of data acquisition, improved value.

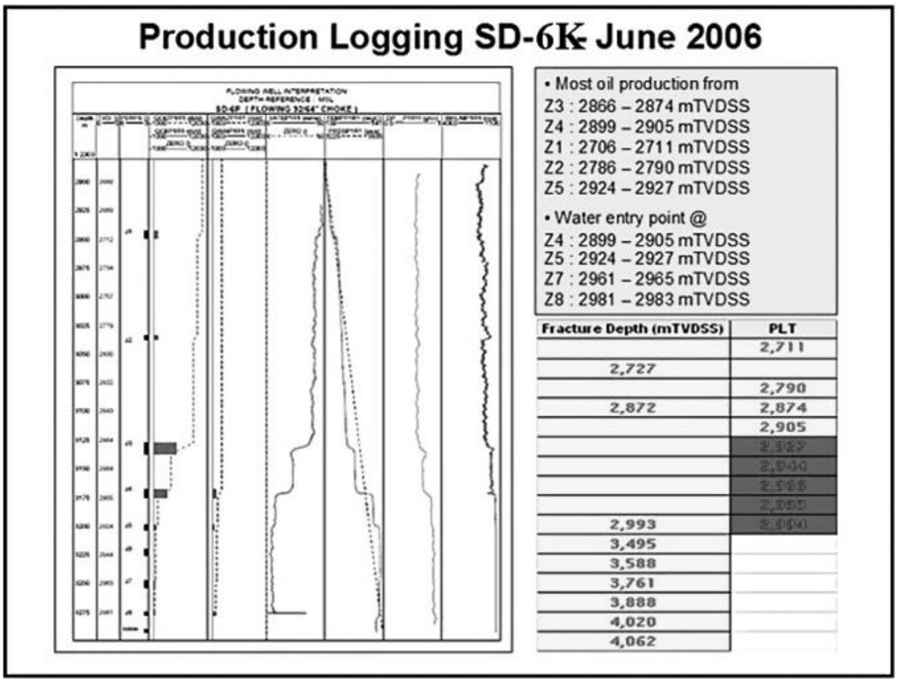

Figure 8. MPLT interpretation results conducted on SD-6K.

4.4. Reservoir monitoring

Interference testing may be undertaken in certain cases to determine connectivity between wells for better water-flooding management.

Pressure surveys conducted during long term shut-in for determining reservoir pressure. These long term pressure surveys not only have been carried in producers but also have been carried out in injection wells to determine reservoir oil-water contact.

Tracer material has been and will continue to be injected into the new injection wells to improve the understanding of water flow through the reservoir. Improved understanding of water flow patterns in the reservoir will assist in designing injection programs to maximize oil recovery.

Tracer analysis has been conducted on samples taken directly from well head to detect injector to producer interactions and water breakthroughs. Samplers have been installed on the producing wells to facilitate capturing water samples for the tracer survey program. Produced water samples will be sent to the lab regularly for analysis. Any changes in water composition will be observed by conducting Tracer and Chemistry analysis routinely. Tracers were injected into injectors and their movement analysis in the basement reservoir has been summarized on figure 9.

Injection wells will be ramped up and the pressure response monitored in offset wells to increase understanding of reservoir connectivity in order to optimize production and injection rates.

Periodic fluid samples will be obtained to determine any changes in fluid composition and PVT parameters.

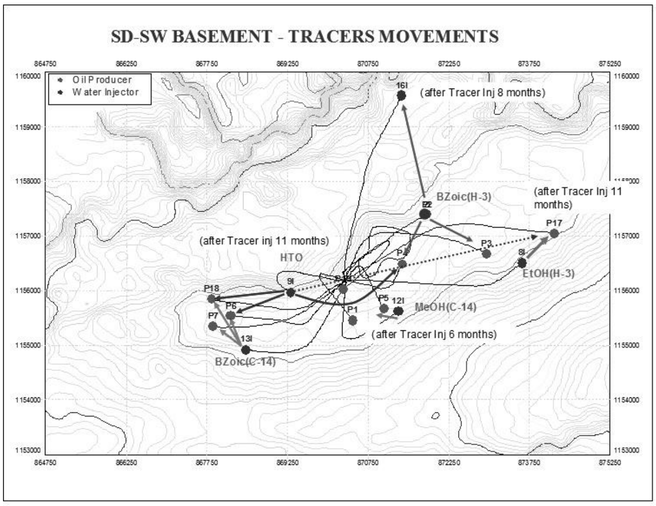

Figure 9. Tracer movement analysis results.

4.5. Production technology diagram updating and revising

The production target is under saturated oil in fractured basement reservoir, no bottom water aquifer, low gas oil ratio (GOR), the main energy resources are fluid and rock expansion really low and in fact in order to maintain the reservoir (above the bubble point pressure) the sea water injection method has been applied [3].

From study in water injection in SD oilfield (no strong water drive) there are at least 9 injectors which located by belt model (figure 10, 11).

The study results also showed out appropriate time and flow rate of injectors as follow:

Star injection after 06 months of production;

Drilling at least 03 injectors in first year;

Late injection could decrease cumulative production;

Injection by belt model;

Injectors design (figure 10):

Injection @ the depth below 3,500 m deep,

The well orbit parallel to reservoir slope,

To avoid direct inject to producers.

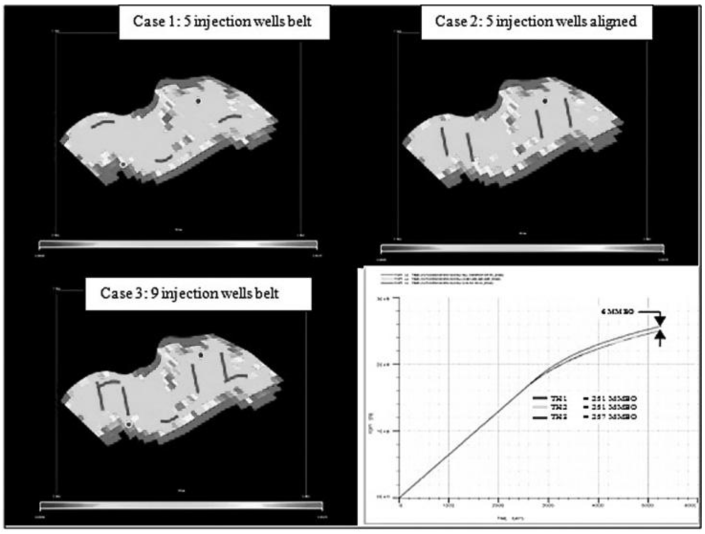

Figure 10. The density of injector.

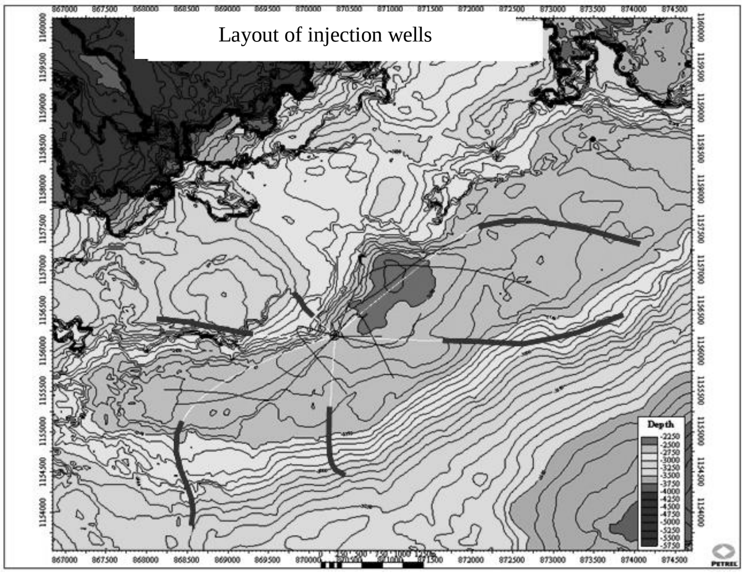

Figure 11. An example of injectors.

4.6. Predicting the water invasion level to reservoir

The water invasion level to reservoir should be predict based on data of formation water volume, reservoir rock characteristics, reservoir heterogeneous, hydraulic conductivity, density and distribution of faults and fractures.

Particularly, based on scenario with production accumulation from 251 ÷ 257 MMBO, averaging after 1,300 ÷ 1,800 days water intrusion phenomenon seams began to influx and gradually increase over time, to about 5,200 days the production water ratio increase reaches to the critical value, fractional water cut (FWCT) are # 80% (figure 12).

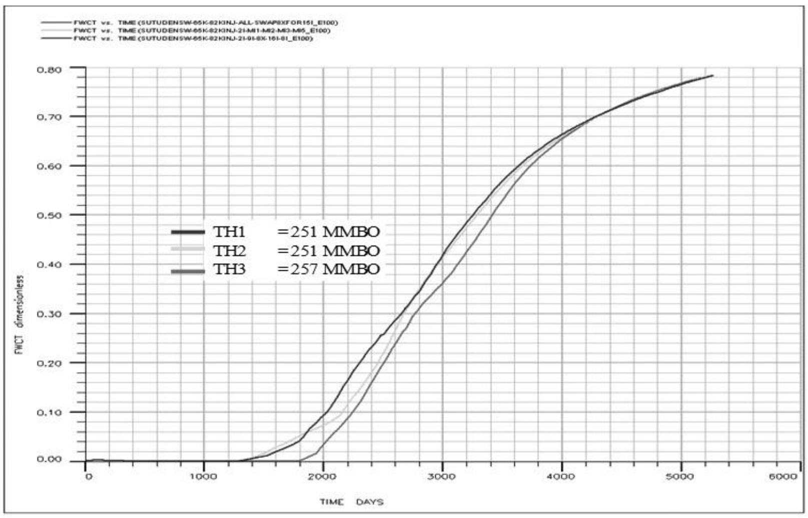

Figure 12. Predicting for time and velocity of water influx .

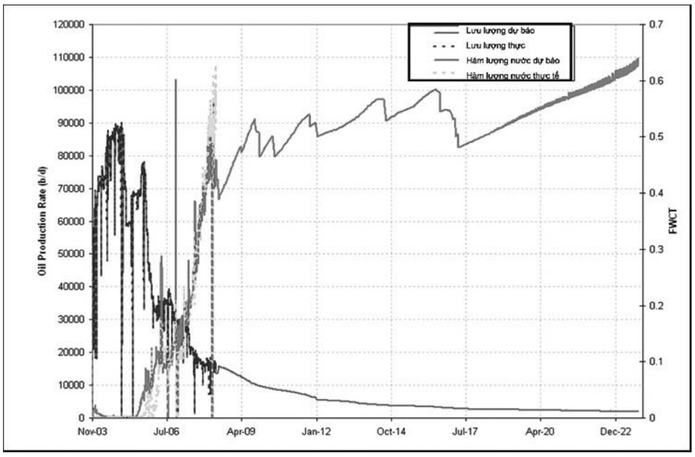

Figure 13. Predicting for flow rate and water cut variation.

Besides it, the production history also shows there are contrary correlation over time between flowrate and water cut ratio, in fact in the case there is no appropriate impact measurements applied, usually after 3,350 days from first oil, the water influx have risen to very high fraction, accounting for most of the production content > 65%, the flow of the main product (oil) dropped below a critical economic value, # 350bbls/ day (figure 13).

4.7. Proposed solution for water influx prevention

Once the reservoir is water invaded, the invasion velocity usually increasing quickly, causes many consequence such as overload water treatment system, consume high chemicals, environment impact, and over all decreasing cumulative production, erroneous cumulative production prediction…Therefore determine the instant and long term solutions to prevent water influx are quite imperative.

4.7.1. Instant solutions to prevent water invasion

1rst solution: ***reducing the flow rate:*** at SD oil field by applied this solution the water cut is initially controlled (figure 14). When water cut began to occur, the flow rate is decreased (choke reducing) appropriately, the water cut always maintain at 0% until the well is abandon and bring more 8% cumulative production from each individual well.

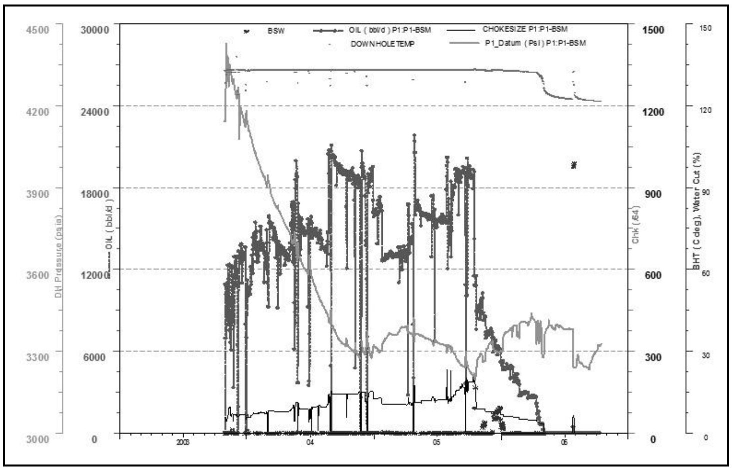

Figure 14. Decreasing flow rate to control water cut.

2nd solution: **revising the production regime and appropriate injection** (figure 15)

The producers should regular spread out in all reservoir area in order to balance the pressure decrease of producers, the injectors chosen when the water cut of closest producer do not suddenly increasing.

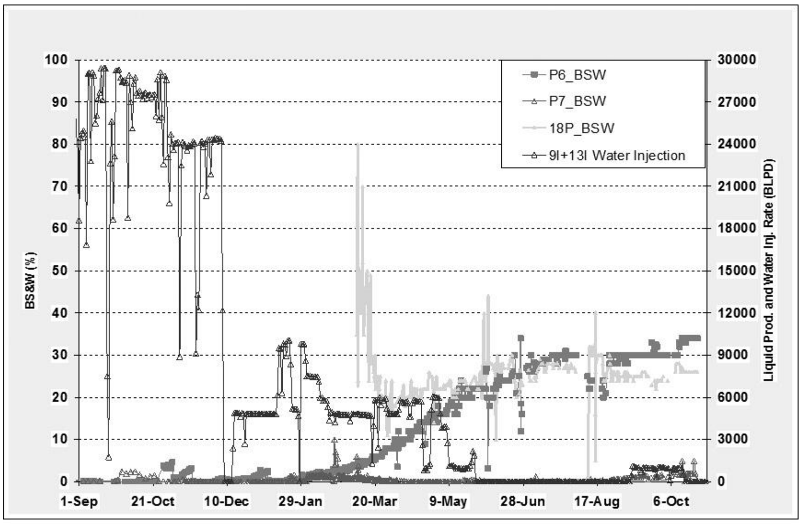

Figure 15. Revising the production and injection regime.

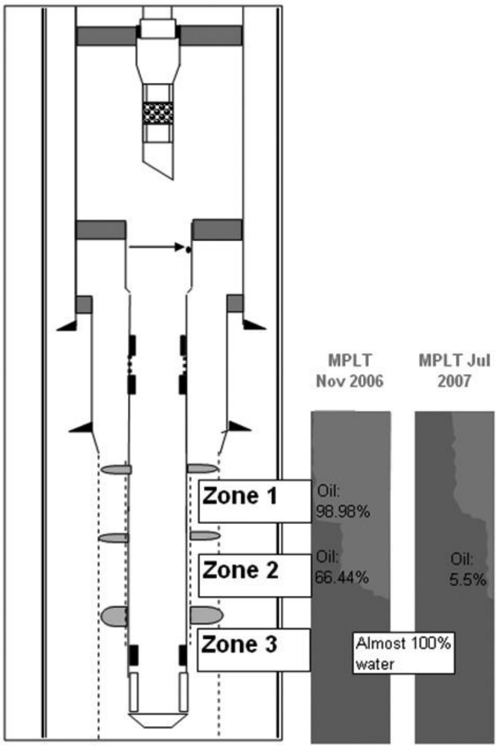

Figure 16. Installing water plug.

3rd solution: based on MPLT, to determine the water influx zone and install the water plug backs to isolate water produced zone or fractures.

An example of MPLT (figure 16) showed the water produced # 96% from zone 2 deep down. After water plug back is installed, the produced water decreased from 90% down to 60%.

4.7.2. Long term prevent solution

Reservoir management of the SuTu Complex reservoirs will allow to drainage efficiently and help identify un-depleted areas for further development and maximize recovery. Close monitoring of each well is vital for optimal reservoir management. Reservoir pressure data will be used in reservoir simulation to assist in history matching and therefore improve confidence in models and allow for improved planning of development wells and to improve reliability of production forecasts.

The oil zone of the SuTuDen field has a low bubble point and in this area gas cap formation and production are not a matter; the reservoir pressure in these areas will be maintained above the bubble point pressure by using water injection to provide optimal pressure maintenance. The optimum reservoir pressure will be determined through reservoir simulation studies and performance analysis. This target will be reviewed periodically and adjusted as needed as additional performance data and analysis is available [4].

Injection volumes and production volumes will be controlled to optimize the reservoir pressure and maximize recovery (figure 16).

The impact of water break-through may be minimized through work-over programs such as plug backs, sidetracks and re-completions.

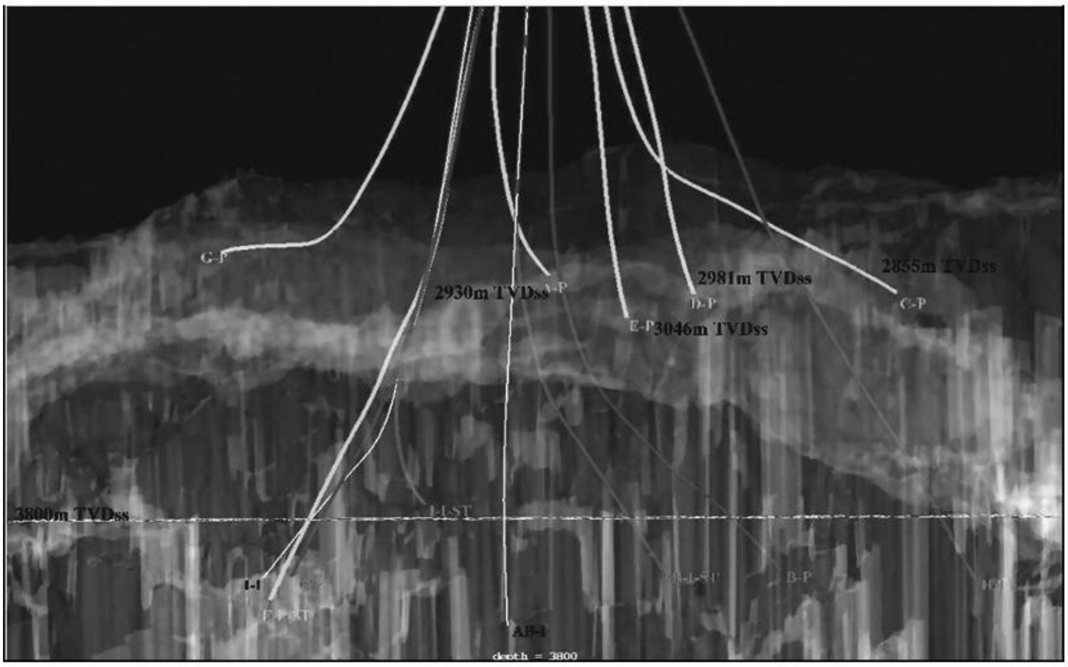

Figure 16. Layout of producers and injectors.

5. Conclusions and recommendations

Study results have proved all formation water, injection water and mudlosses were present in produced water. Among them, formation water dominantly contributed about two thirds proportion to produced water of SD field generally. However, their proportions were timely dependent and varied from well to well.

The impact of water break-through may be minimized through work-over programs such as plug backs, sidetracks and re-completions.

Depend on field development, the causes, origins, direction of water invasion need to determined and clarified. Aquifer modeling need to build up in order to installing and applying appropriate technical solution such as reservoir monitoring, well observation, well test, update field designing, developing draft, predicting mechanism of water invasion and at last propose prevention solution (instant, long term) for water influx.

Further study need to be conducted to determine the origins of produced water, especially with basement rock reservoir, regularly update hydrodynamic model based on reality data those come from production and injection wells, determining the effective solutions, optimization production capacity, water injection and enhance oil recovery.

Acknowledgements

I gratefully acknowledge authors B2011-20-15 VNU HCM project for supporting me to carry out this research and Cuulong JOC for providing the data for my paper.

References

[1] Xuan, Tran Van et al, final reports of VNU HCM project, effects of changes in production water concentration to recovery efficiency of SuTuDen oilfield (ảnh hưởng của biến đổi hàm lượng nước sản phẩm lên hiệu suất khai thác mỏ Sư tử Đen), 2013.

[2] CLJOC reports: Well reports, SD & SV FDP, 2007.

[3] Vietnam Petroleum Institute, Determine the source of produced water in SD SW basement reservoir, 2007.

[4] Reservoir Engineering Group, Cuulong joint operating company field: Block 15-1, phase 1 production & injection performance report and future production & injection plan, 2005.

Ảnh hưởng của nước xâm nhập đến quá trình thiết kế, khai thác thân dầu móng nứt nẻ mỏ SuTu Den và giải pháp phòng ngừa

Trần Văn Xuân

Đại học Bách Khoa Tp Hồ Chí Minh, 268 Lý Thường Kiệt, Q 10 Tp Hồ Chí Minh

Tóm tắt: Trong quá trình khai thác dầu khí, đặc biệt trong thân dầu móng nứt nẻ có quan hệ thủy lực với nước thành hệ, khả năng nước xâm nhập hoàn toàn có thể xảy ra. Trên cơ sở số liệu thu thập được từ thực tế hoạt động khai thác dầu, bơm ép nước tại mỏ SuTu Den, bể Cửu long, Việt nam, tác giả đã tiến hành nghiên cứu, đánh giá ảnh hưởng của nước thành hệ lên thân dầu móng trong từng giai đoạn từ thăm dò, thẩm lượng, phát triển đến khai thác, xác định giải pháp, công nghệ phù hợp để hoàn thành mục tiêu nghiên cứu đã đề ra. Trong giai đoạn thăm dò, với trường hợp áp dụng cụ thể, như giếng khoan quan trắc, giám sát mỏ, thử vỉa, cập nhật hiệu chỉnh sơ đồ công nghệ khai thác, dự báo khả năng, mức độ nước xâm nhập vào mỏ, bài báo đã xây dựng cơ sở lý thuyết cho việc đề xuất các giải pháp tức thời (giảm lưu lượng khai thác, điều chỉnh chế độ khai thác-bơm ép nước, cách ly những đới có khả năng bị ngập nước) cũng như những giải pháp dài hạn (giám sát chặt chẽ động thái áp suất của giếng khai thác, tối ưu hóa việc thiết kế khai thác-bơm ép, xác định và lượng hóa nguồn gốc của nước sản phẩm) nhằm phòng chống hiện tượng nước xâm nhập từ đó nâng cao hiệu suất thu hồi dầu.

Từ khóa: Thân dầu móng nứt nẻ, nước thành hệ, khai thác và bơm ép, thiết bị kiểm tra khai thác (PLT), thử vỉa bằng bộ khoan cụ (Drill Stem Test), mô hình thủy động, hàm lượng cặn và nước (BS&W), thu hồi dầu tăng cường (EOR).