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Comparative Study of Plug and Abandonment Using Balanced Plug Cementing Method: Case Study of Well "NOV-01" field "VITA"

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ABSTRACT - The NOV-01 well is a directional well that has technical problems (fish), namely the stuck pipe problem and the problem of high land use operational costs. Based on the results of the evaluation of the economic and risk technical aspects, a plug & abandonment (P&A) was carried out for the NOV-01 well. The purpose of this research is to compare the 3 stages and 5 stages in P&A work and their influence on work program planning and budgeting. The research methodology is qualitative and quantitative. The NOV-01 well plug and abandonment activity is carried out by preparing a work program plan such as determining the depth interval of the well to be plugged, the volume of cement slurry & additives, as well as the rig method which all refer to the existing standards and regulations, namely SNI 13-6910-2002 and NORSOK D-010. The results of a comparative study on P&A planning at 3 stages required 279 sacks of cement and 450 sacks of cement at 5 stages with a density of 15.8 ppg. P&A on well NOV-01 uses the rig method with a capacity of 450 HP. For 3 stages it takes 9 days and 5 stages for 11 days. Comparison of estimated costs for P&A of NOV-01 well, namely 3 stages of IDR 6,062,977,890.31- and 5 stages of IDR 8,374,824,218.62-. Well NOV-01, P&A which is suitable is 5 stages because there is an overpressured zone so that the cement plug is isolated.

Keywords: fish, plug & abandonment, rig method, work program

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INTRODUCTION

Plug and abandonment is a process of closing the well permanently. This activity involves closing the wellbore again and securing it for several months to years or permanently because the well is no longer economical to produce. The main objective is to ensure that there is no leakage to the surface and no migration of formation fluids occurs even after years of abandonment of the well. Well closures are undertaken to effectively seal off all potential hydrocarbon-carrying zones from the water zone and to protect zones that may contain other minerals that might cause problems. Cementing operations that are not successful perfectly can cause many problems, including the closure of productive formations and the difficulty of controlling water production in productive formations (Saroyo 2014). In order for the purpose of cementing to be achieved, cement must have properties that can function properly in the conditions of each well. In some cases old abandoned wells often experience annular leaks or loss of casing integrity which can further complicate plug & abandonment operations. These cases often require the operator to cut and pull the tubular tubing or part factory casing to gain access to the leak interval and seal it. Therefore, it is necessary to have good planning from a technical and operational point of view, so that this case does not occur when the plug and abandonment work is to be carried out. In oil wells, indicators of the success of plug cementing are seen from the compressive test after cement is placed in the well (Fitrianti et al. 2020).

Well "NOV-01" is an exploratory well which was then continued with re-entry work in 2020, but experienced a pipe stuck which caused part of the series to be left in the wellbore (fish). In the re-entry work, it indicated that work could not be resumed due to problems well control issues and pipe stuck problems so that the "NOV-01" well is temporarily suspended. Based on operational studies, fishing operations in the "NOV-01" well can no longer be carried out, and the option of side track drilling has a high potential risk from an operational standpoint so that it will have an impact on the project's economics. Therefore, Well "NOV-01" was determined to carry out permanent plug & abandonment well work, which currently has a temporarily suspended status and is a leased area, and it is not economical to continue operations. Wells that are no longer used for economic activities must be abandoned in accordance with applicable regulations. There are several problems that may occur in the well, so that needs to be considered when implementing a plug & abandonment well.

In well NOV-01, fish problems occurred start with a problem stuck pipe which caused several Bottom Hole Assembly (BHA) circuits in the drill hole. Top fish is at a depth of 3737 ftMD. The total depth of fish is from 3737-4145 ftMD, with a total length of 408 ftMD left behind. To overcome these problems, several fishing job operations have been carried out, but they were not successful and will increase the cost of the activities carried out so that they are considered uneconomical. In addition, well NOV-01 is located in a residential area managed by the Gresik area, East Java. Therefore, to continue operating the well requires a land lease of ± 1 billion/month. After the economic evaluation was carried out, the condition of the well which had a fairly high risk and used leased land, caused the marginal economic of well NOV-01 to become uneconomical from operations could not be continued.

METHODOLOGY

The methodology used in this research is qualitative and quantitative. Qualitative methods are used to analyze the problems that occur in the wells and a comparative study analysis is carried out for 3 stages and 5 stages in plug and abandonment work. Quantitative methods are used to calculate the work program, especially the slurry, additives and completion fluids used as well as the costs required for plug & abandonment (P&A) activities. In addition, in planning P&A work, the method used is the balance plug cementing method. In principle, the balanced plug cementing method places a cement column on the drillpipe whose height must be the same as that of the annulus (Nelson, 2006) to ensure that the hydrostatic pressure in the drillpipe and annulus is equal (balanced). For more details on the methodology can be seen through the flowchart in Figure 1.

RESULTS AND DISCUSSION

Research Data

Research data in this study were obtained from Well NOV-01 in Field VITA which is located in Tuban, East Java. The data available in this study are well schemes, well completion, tubing details, casing details, well perforation depths, and cement information in several casing strings. The data will be used for planning cement volume, additive volume, completion fluid volume, work program, operating time, and economics for 3 stages & 5 stages of plug and abandonment work. In addition, for analysis and comparative analysis of the two cement plug stages so that optimum results are obtained for plug and abandonment work.Well NOV-01 is an oil exploration well with temporarily suspended status which will continue with plug and abandonment work. This is because the well has fish problems along 408 ftMD and the economy of the land. The series of BHA left in the well are 5-3/4" OS, 3-1/2" HWDP, 4-3/4" DC, 4-3/4 Jar, 4-3/4" MM, and 6 "TCB. Then, the tubing used in the plug and abandonment operation is 2.875 inch. In well NOV-01 plug and abandonment work program work, for 3 stage planning refers to SNI-13-6910-2002, while for 5 stage planning refers to NORSOK D-010.

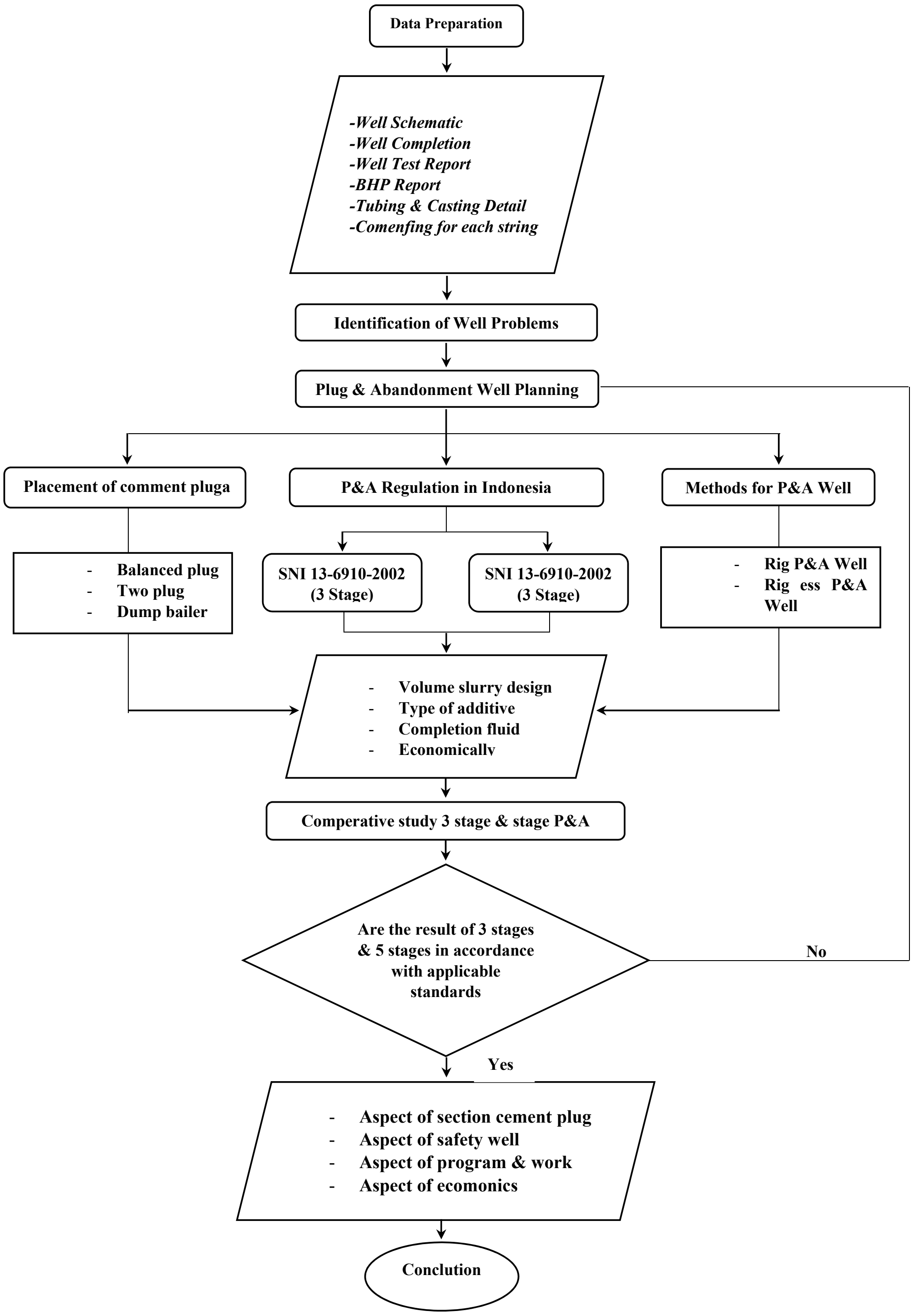


Figure 1
Research Flowchart

Plug and Abandonment for Well NOV-01-01

Work program plug and abandonment well NOV-01, for planning 3 stages refers to SNI-13-6910-2002, while for planning 5 stages refers to NORSOK D-010. Each work plan consists of several stages which will be explained in the following point.

SNI-13-6910-2022

In planning a cement plug to close the perforation interval zone, namely at a cement plug depth of 3637 – 4145 ftMD. At this stage, in planning, the author has referred to regulation SNI-13- 6910-2002 which states that cement plugs must be installed by the pushing method through the entire perforation interval and cement plugs must reach all perforation intervals of at least 100 ft above the perforation interval up to minimum 100 ft below the perforation interval or to the nearest casing plug. If there are two perforation intervals that are closely spaced, one cement plug is cemented.

- Planning a cement plug at a depth of 3077-3277 ftMD on casing stump blockage. At this stage, the author refers to regulation SNI-13-6910-2002 which states that if the casing is cut and removed, the casing stump must be plugged with a cement plug that reaches a minimum of 100 ft above the stump and 100 ft above the top of the liner.
- A cement plug at a depth of 0-150 ftMd for surface plugs. At this stage, the author refers to the regulation SNI-13-6910-2002 which states that the surface cement plug has a length of at least 150 ft. Cement plugs should be placed in the smallest casing that reaches the mudline.

NORSOK D-010

- A cement plug to cover the perforation interval zone or primary well barrier, namely at a cement plug depth of 3500 – 4145 ftMD. At this stage, in planning, the author has referred to NORSOK D-010 regulations by placing a cement plug which functions as a barrier to the main well against the flow of formation fluid and isolates potential sources of inflow to the surface.
- A cement plug for isolating the top of the liner at a depth of 3000-3177 ftMD as a well barrier because at the top of the liner usually cement is not carried out as is the case for the casing for the annulus, therefore the P&A top of liner needs a cement plug . Placement of the cement plug is carried out on top of the next casing shoe until it reaches the top of the liner.
- Planning of cement plugs for hydrocarbon bearings at depths of 1625-1775 ftMD as isolation in each part of the casing shoe. Based on the NORSOK D-010 standard, for each casing shoe it is necessary to carry out a cement plug as a secondary well barrier or back-up to the primary well barrier.
- A cement plug at a depth of 522-672 ftMD as isolation in each part of the casing shoe. Based on the NORSOK D-010 standard, for each casing shoe it is necessary to carry out a cement plug as a secondary well barrier or back-up to the primary well barrier.
- Planning cement plugs for hydrocarbon bearings at a depth of 0-150 ftMD as isolation from the water zone (fresh water). Based on the NORSOK D-010 standard, to minimize the risk due to contamination with intervals containing fresh water, a cement plug is placed to isolate all fresh water intervals. Most of this fresh water is generally in shallow wellbore so that it can do with the surface plug zone.

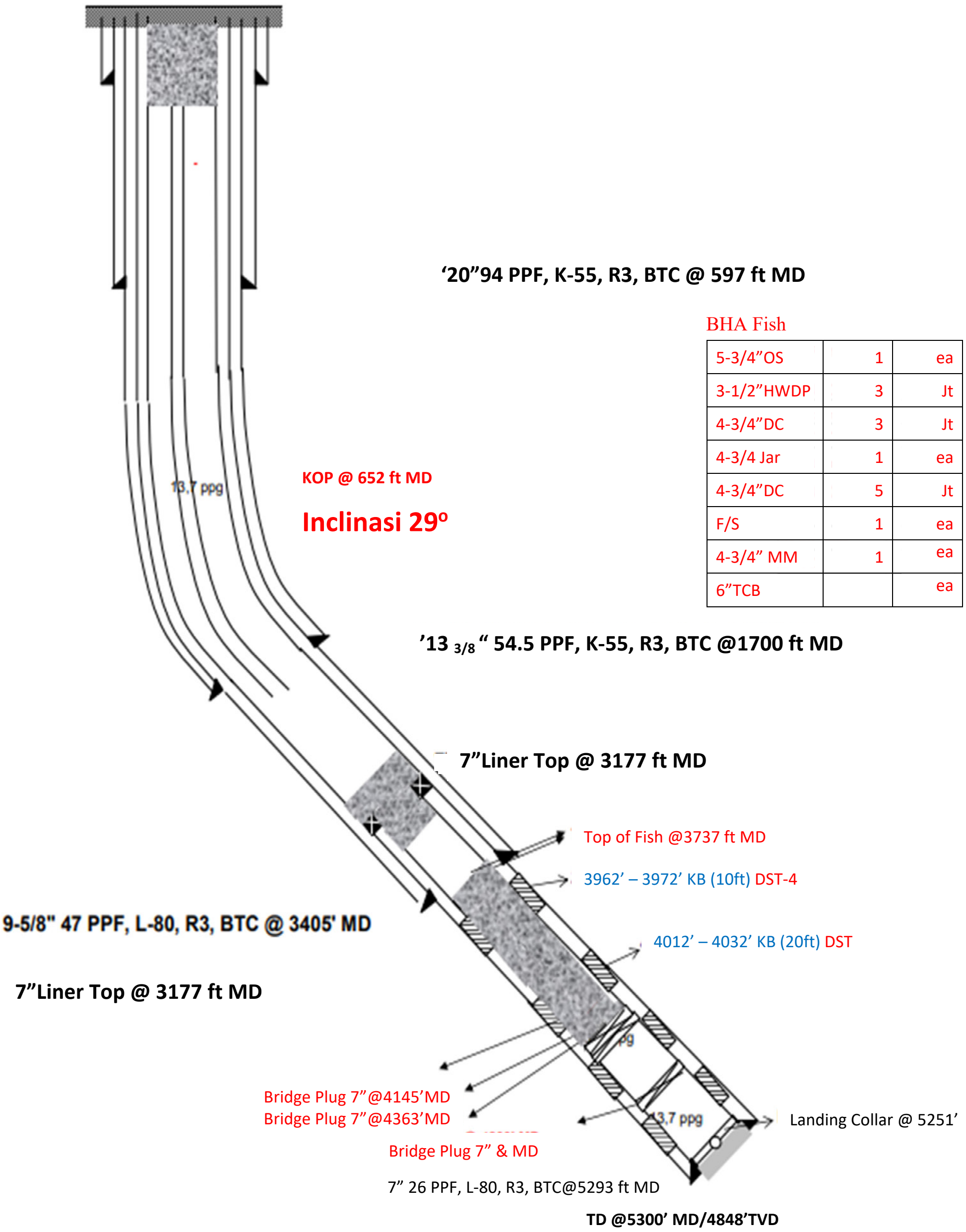
Best Practice. The best practices included in this paper were developed from a literature review referring to field case studies of plug and abandonment work. This paper describes options that should be considered during well-abandonment planning and describes the options that should be considered during good plug and abandonmnet planning. Ultimately, however, the operator must decide how the well will be abandoned and whether this practice will be beneficial from a safety perspective when the well is permanently abandoned and to protect the environment.

Cement Design. Cement plugs shall be designed for static bottom hole conditions at each plug setting depth. Expected bottom hole pressure and temperature are controlling factors in slurry selection. The slurry density shall be designed for bottom hole pressure. Additive concentration should be based on bottom hole temperature to ensure proper placement time and compressive strength development. In the plug cement design for well NOV-01 using class G cement with additional additives namely silica flour, defoamer, friction reducer cement, fluid loss control, anti migration gas, and gelling agent. Each piece of cement plug uses a different volume of additive.

Cement Placement. Cement should be placed in a clean and known environment. Placement of the cement plug in well NOV-01-01 uses the balanced plug cementing method. This method can be an effective and inexpensive way to isolate a perforation, but it is not without risks. This method works by lowering the drillpipe into the wellbore to the destination where the cement plug will be made. To avoid mud contamination, adjust the volume of the spacer that will be pumped from top to bottom of the cement slurry. The pre-flush is pumped before the cement and then followed by a spacer or limiting fluid.

Calculation of P&A

The following is an example of calculating the cement plug volume for the perforation zone. Based on calculation the column length of cement from bottom perforation to top perforation is 70 ftMD. Add safety margin of 100 ftMD above the top perforation and 100 ftMD from the bottom perforation in accordance with regulations and standards, the results is 508 ftMD. Calculation the volume of cement slurry needed to filling the casing column is 19,46 bbl. From count the total perforations is 350 hole/ft with volume of cement slurry that enters the perforation hole is 6,23 bbl. From this, height of the cement when the string (tubing) is in the wellbore is 763,23 ftMD with top of cement (TOC) when the string is in the wellbore 3381,77 ftMD. Total cement slurry required for the perforation zone included cement slurry for volume casing, volume cement slurry in perforation zone, and volume cement slurry with dead volume is 29,68 bbl. Total sack of cement required, slurry yield = 1,19 cuft/sack is 140 sackFrom the calculation of cement volume referring to SNI-6910-2002 and NORSOK D-010 standards, the total volume of cement slurry for P&A obtained from each regulation is as follows:



5-3/4"OS	1	ea
3-1/2"HWDP	3	Jt
4-3/4"DC	3	Jt
4-3/4 Jar	1	ea
4-3/4"DC	5	Jt
F/S	1	ea
4-3/4" MM	1	ea
6"TCB		ea

Figure 2
P&A Design with SNI 6910-2002

The following is a tabulation of cement plug volume calculation results based on SNI 6910-2002 standards.

Table 1
Cement Slurry P&A SNI-6910-2002

Cement Plug	Length of Cement, ftMD	Cement Volume, bbl	Quantity. Cement, sack
I	508	29,68	140
II	200	15,15	70
III	150	14,98	69
Total		59,82	279

A comparative analysis was conducted to find out the advantages and disadvantages of each regulation for plug and abandonment well work. This comparative analysis will later be used to select the appropriate regulation by taking into account the condition of the wells and the economics of P&A activities. The following is a comparison of the SNI-6910-2002 (3 stages) and NORSOK D-010 (5 stages).

Cement Plug Section

Based on SNI-6910-2002, cement plugs are placed in the perforation interval isolation zone, top isolation of liner, and surface insulation. The placement of the cement plug does not take into account the existence of an overpressured zone, so it is necessary to mitigate if a problem occurs during the P&A work. For each part of the casing shoe section it is not required to place a cement plug with the consideration that the pressure that the cement plug has is able to withstand the formation pressure in the well. The hydrocarbon zone is considered one, that is, from the well and there are no other hydrocarbon zones around the well so that the isolation of the hydrocarbon bearing zone is ignored.

Refers to NORSOK D-010 in Figure 3, cement plugs are placed in perforation interval isolation zone as a primary well barrier, top of liner isolation, hydrocarbon bearing isolation or overpressured zone as a secondary well barrier, isolation for each section of casing shoe, and isolation of the surface water zone (fresh water). Placement of the cement plug takes into account the existence of an overpressured zone or abnormal pressure, therefore, it is necessary to place a cement plug across the transition interval, where the length of the plug is at least 200 ft or at least reaches normal pressure in certain casing sections. In each section of the casing shoe, it is necessary to carry out cementing by considering the differences in formation for each section and changes in rock lithology. Considering a zone that contains other hydrocarbon intervals around the well so that a cement plug is needed in that zone.

Safety of P&A

SNI-6910-2002, isolation at 3 stages of cement plug has fulfilled the safety aspect for P&A work so that problems can be minimized. If there is a risk of gas contamination or there is an overpressured zone, this should be considered when using a 3 stage cement plug, show in the Figure 2.

The isolation of the fresh water zone serves to prevent surface contamination from unwanted things. The risk of contamination by gas or overpressured zones can be avoided by placing a cement plug. Conditions to maintain formation pressure in the well are safer for NORSOK D-010, show in the Figure 3.

Table 2
Cement Slurry P&A NORSOK D-010

Cement Plug	Length of Cement, ftMD	Cement Volume, bbl	Quantity. Cement, sack
I	645	34,93	165
II	177	16,95	78
III	150	14,98	69
IV	150	14,98	69
V	150	14,98	69
Total		96,83	450

Work and Program

In terms of program and work time using a 3 stage cement plug, namely 9 days of operation. In terms of program and work time using a 5 stage cement plug, namely 11 days of operation.

Economic Analysis

The costs required for the SNI-6910-2002 (3 stage) P&A operation are IDR 6,062,977,890.31 or USD 389,401.28. The costs required for NORSOK D-010 (5 stage) P&A operation are IDR 8,374,824,218.62 or USD 537,882.09. With a 5 stage cement plug, the costs incurred will be higher with more cement volume. In well NOV-01, the type of cement plug that is suitable for use is 5 stage cement plug. This is because well NOV-01 has an overpressured zone so it is necessary to isolate or place a cement plug in that zone. In addition, it also takes into account changes in rock lithology for each casing section, so that the placement of cement plugs in each casing section is to consider the safety of the well when abandoned in the long term.

CONCLUSIONS

Based on the results and discussion of comparative study of plug & abandonment using balanced plug cementing method, it can be concluded well NOV-01 is planned for plug & abandonment by reason of problems with fish availability and well economy. The plug and abandonment technique used is using a rig with a power rating capacity of 450 HP for a total depth of 5300 ftMD with a drillpipe size

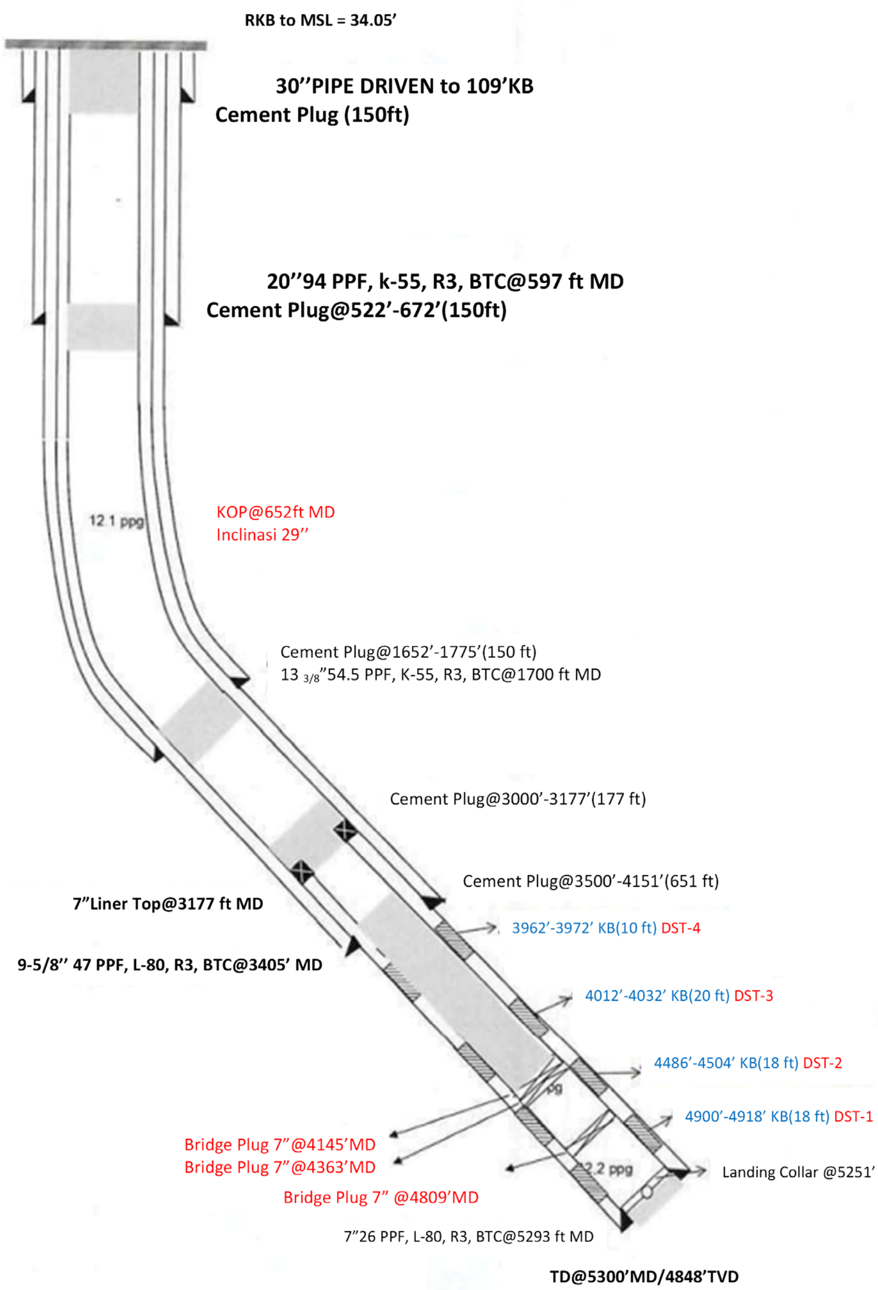


Figure 3
P&A Design with NORSOK D-010

of 3 ½ inches. P&A work for the SNI-6910-2002 standard (3 stages) takes 9 days of operation, while for NORSOK D-010 (5 stages) it takes 11 days of operation. Based on economic analysis, a comparison of the estimated costs required for P&A work, namely for the 3 stages is Rp. 6,602,977,890.31 - or the equivalent of USD 389,401.28 -, while for the 5 stages, it is Rp. 8,374,824,218.61 - or the equivalent of USD 537,822 ,09-. From economical analysis for plug & abandonment work program 3 stage is more efficient than 5 stage.

In the "NOV-01" well, taking into account the condition of the well, the type of cement plug that is suitable for use is 5 stage cement plug which refers to the NORSOK D-010 standard.

ACKNOWLEDGEMENTS

The authors would like to thank PT Pertamina EP Cepu, UPN "Veteran" Yogyakarta, and all stakeholders who have assisted in the preparation of this journal.

GLOSSARY OF TERMS

Unit	Definition	Symbol
MD	Measured depth	ft
TVD	True vertical depth	ft
SPF	Shoot per foot	cuft/hole
Sann	Capacity of annulus	bbl/ft
Csg	Casing	inch
DP	Drill pipe	inch
TOC	Top of cement	ft
P&A	Plug & abandonment	

REFERENCES

Adam, N. J., Tommie, C., 1985, 'Drilling Engineering- A Complete Well Planning Approach', Research Associate, PennWell Publishing Company, Imprint Tulsa, Okla, 288-291.

Afrisca, C. C, 2020, 'Evaluasi Rigless Plug & Abandonment: Sebuah Studi Kasus. Jurnal Nasional Pengelolaan Energi Migas', 2, 09-2

Juventa, Ahmad, F. B., Nasri, M. Z., Fitriyanda, H., Ahmad, D. F. 2022), 'Karakterisasi Reservoir Karbonat Menggunakan Inversi Impedansi Akustik Blok 'X', Formasi Tuban, Cekungan Jawa Timur'. Jurnal Geosaintek, 8, 173.180.

Kelm, C. H., Ronnie, R. F., 1999, 'Well Abandonment-A "Best Practices" Approach Can Reduce Environmental Risk', Paper Presented at the SPE Asia Pasific Oil and Gas Conference and Exhibition, Jakarta, Indonesia, 20-22 April, SPE 54344, 3-4.

Nelson,E. B., Dominique, G., 2006, 'Well Cementing, Second Edition, Schlumberger, Sugar Land, Texas, ISBN-13:978-097885300-6., 513-514.

PT Pertamina EP., 2012, 'Drilling Standart Operating Procedure BAB 37. Plug and Abandonment Well'.

Rabia, H., 2002, 'Well Engineering & Construction', Entrac Consulting Limited, London, 171-172.

Saroyo, B., 2014, 'Desain Formulasi Semen Ringan (Light Weight Cement) untuk Mitigasi Kerusakan Formasi Akibat Penyemenan pada Sumur GMB', Journal Lemigas, Pusat Penelitian dan Pengembangan Teknologi Minyak dan Gas Bumi, 48, 3, 119-132.

The Norwegian Oil Industry Association., 2012, 'Well Integrity in Drilling and Well Operations', NORSOK Standard D-010, Norway: Standards Norway.

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The 3D Seismic Survey Design of South Walio Offshore, Indonesia: Optimizing the 3D Survey Design Parameters

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ABSTRACT - The background of this research is to support the plan to carry out 3D seismic acquisition in the Salawati Kepala Burung Working Area located in Sorong Regency. The 3D seismic design study was applied to better understand the physical properties of the Mesozoic clastic reservoir in the Salawati basin and its surroundings, especially in the offshore area. The study aims to evaluate the parameters of a reliable 3D seismic acquisition design to meet efficiency in financing in realizing the 3D seismic data acquisition program. Determine the recording parameters to image the Kais Formation and Waripi Formation targets by building a geophysical analysis model using existing 2D data and well-log information. Based on this model, using the Kais and Waripi formation properties to calculate and analyze vertical and horizontal resolution, bin size, aperture migration, and maximum offset. Synthetic acquisition 2D modeling is applied in this study to perform vertical and horizontal resolution analysis and obtain optimum and reliable bin size parameters and aperture migration. With this knowledge, we calculate the theoretical parameters of the survey. After determining the most critical theoretical parameters of the study, the next step is to determine the distance between the source and receiver. Then define the recording template. It is done by considering the bin size for the 3D model, offset boundaries, and suitable folds for inner targets. In the second, an analysis of the other two most important attributes is carried out, namely the offset and azimuth distribution. It is realized that every 3D survey design compromises technical factors affecting 3D survey costs starting from the technical requirements of field activities. The results of this study are recommendations and suggestions for two main alternative models of recording parameters and templates in the form of ideal source-receiver layout models, namely orthogonal and diagonal, and the minimum prerequisites that are expected to be able to map and determine the characteristics of the shallow and deep play type models in the South Walio offshore areas.

Keywords: 3D survey design, salawati basin, salawati working area, kais formation & waripi formation, parameter recording & templates

How to cite this article:

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INTRODUCTION

General

This study is addressed to support the 3D seismic acquisition plans in the Salawati area. In which the 3D seismic design is applied to realize the exploration mindset to go deeper to understand better and explore the Mesozoic clastic reservoir. It is suggested that better definition and possible characterization of the reefal facies' existence may be possible when the new seismic data is with the proper seismic data acquisition parameters. According to Doust & Noble (2008), Aifam–Roabiba's petroleum system is critical since it gives rise to most new LNG projects. More than 18 tcf has been certified for the gas reserves in the Tangguh field area. The existence of a secondary target reservoir is in the Palaeocene turbiditic sandstone. However, the reservoir properties appear less uniform than the primary Roabiba petroleum system. It has been suggested by Doust & Noble (2008) that the source of the petroleum system of the Permian/Jurassic began during the Pliocene with widespread subsidence and burial in the western foreland of the Lengguru thrust fault.

To understand the better possible characterization of the reefal facies' existence as well as the existence of a secondary target reservoir in the Palaeocene turbiditic sandstone, the three-dimensional seismic will play an important role in the appraisal and the development planning (Rijks & Jauffred, 1991). The better definition and possible characterization of the facies as well as stratigraphy existence will be possible when the 3D seismic with the optimal parameters for survey design and realization is done in the seismic data acquisition (Moldoveanu, 2003, Stork, 2011, Babu et al., 2022).

This study is also addressed to evaluate the reliable 3D design parameter for better cost-effectiveness in 3D seismic data realization. The strategy is to establish the recording parameters to image both targets of the Kais Formation and deeper targets of the Waripi Formation. The works start by defining the geological and geophysical objectives.

The motivation for this study is to evaluate, analyze, and determine the optimal parameters for survey design and realization of South Walio Offshore seismic data acquisition according to the target of interest, namely the Mesozoic clastic reservoir and a relatively deep exploration target according to the existing subsurface interpretation model. The aim is to provide recommendations for source and receiver layout models and acquisition parameters according to the results of several simulation studies based on available subsurface data. This study will also offer suggestions for improving seismic data quality and optimal 3D parameter design and analysis for the new 3D seismic acquisition program. Thus, this study aims to evaluate reliable 3D design parameters for better 3D seismic data.

The geological and geophysical model of the Reservoir Pay Zone thickness of Kais, Waripi, and Pre-Tertiary Formation based on the Jaya-Deep-1 well are summarized using well log data in Figure 1.

Survey objectives

The primary objective is to apply the 3D seismic design to realize the optimum and reliable parameters for the 3D seismic data acquisition plans, especially for Kais Formation. In addition, it should include imaging any strike-slip (wrench) faults that may exist in South Walio Offshore (Doust & Noble, 2008). The secondary objectives are to map the deeper target of Waripi and Pre-Tertiary. A further aim is to obtain detailed possible stratigraphic information of sufficient quality to map reservoir features and the ability to detect and map the existence of hydrocarbon lead or prospect. 3D data is expected to have a better chance of catching the possible Direct Hydrocarbon Indicator (DHI) with the better imaging inherent in 3D migration. In addition, advanced seismic processing studies may prove fruitful when 3D data is acquired.

Survey area

The South Walio Offshore is a part of the Salawati basin; West Papua is a prolific Basin in Eastern Indonesia, which is proven to produce oil and gas from the Miocene carbonate reservoir, mainly the Kais Reef limestone Formation. The Salawati Basin area is bounded by the Sorong Fault Zone (SFZ) in the north and west. On the southern part, it is determined by the Misool-Onin anticline, and on the west, the Ayamaru Plateau separates the basin from the adjacent Bintuni Basin (Ovinda et al., 2018). According to Doust & Noble (2008), based on regional geological studies showed that the Kais Reef limestone has two types of carbonate reservoirs. The reef carbonate reservoirs have good to excellent reservoir properties, and non-reefal carbonate reservoirs (platforms) have moderate to good porosity and permeability. The carbonate reef of the Kais Formation was suggested to be developed within the carbonate platform without any correlation between one and other reservoir types (Doust & Noble, 2008). However, the Tertiary-Kais Formation system has produced very few commercial oil discoveries. Figure 2 shows the regional stratigraphy of the Salawati Basin (Satyana, 2001). The 3D South Walio Offshore covers an area of approximately 100 square kilometers. The Boundary control points' coordinates are shown in the following Figure 3.

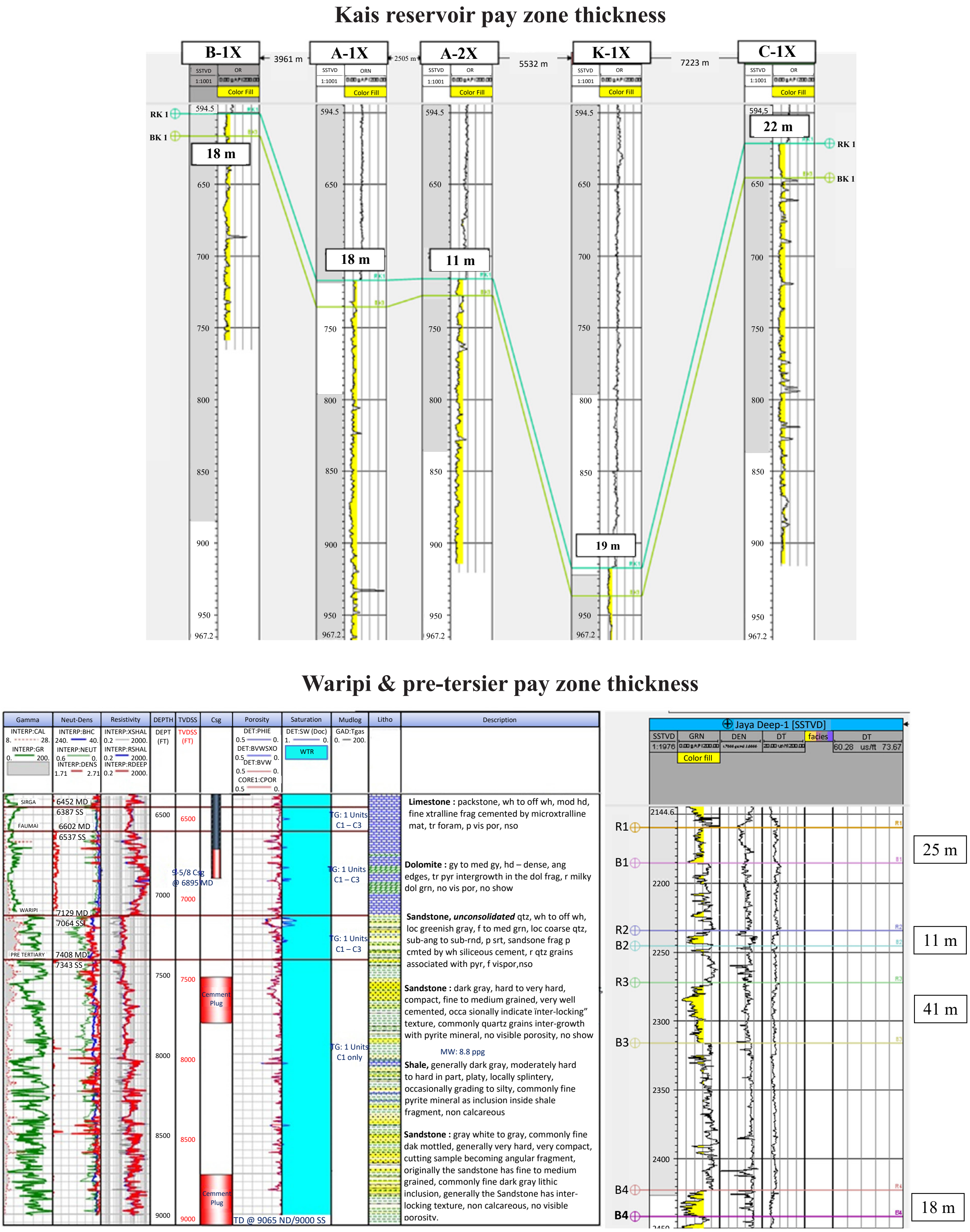


Figure 1
The geological and geophysical model of the reservoir pay zone thickness of kais, waripi, and pre-tertiary formation based on the jaya-deep-1 well are summarized using well log data.

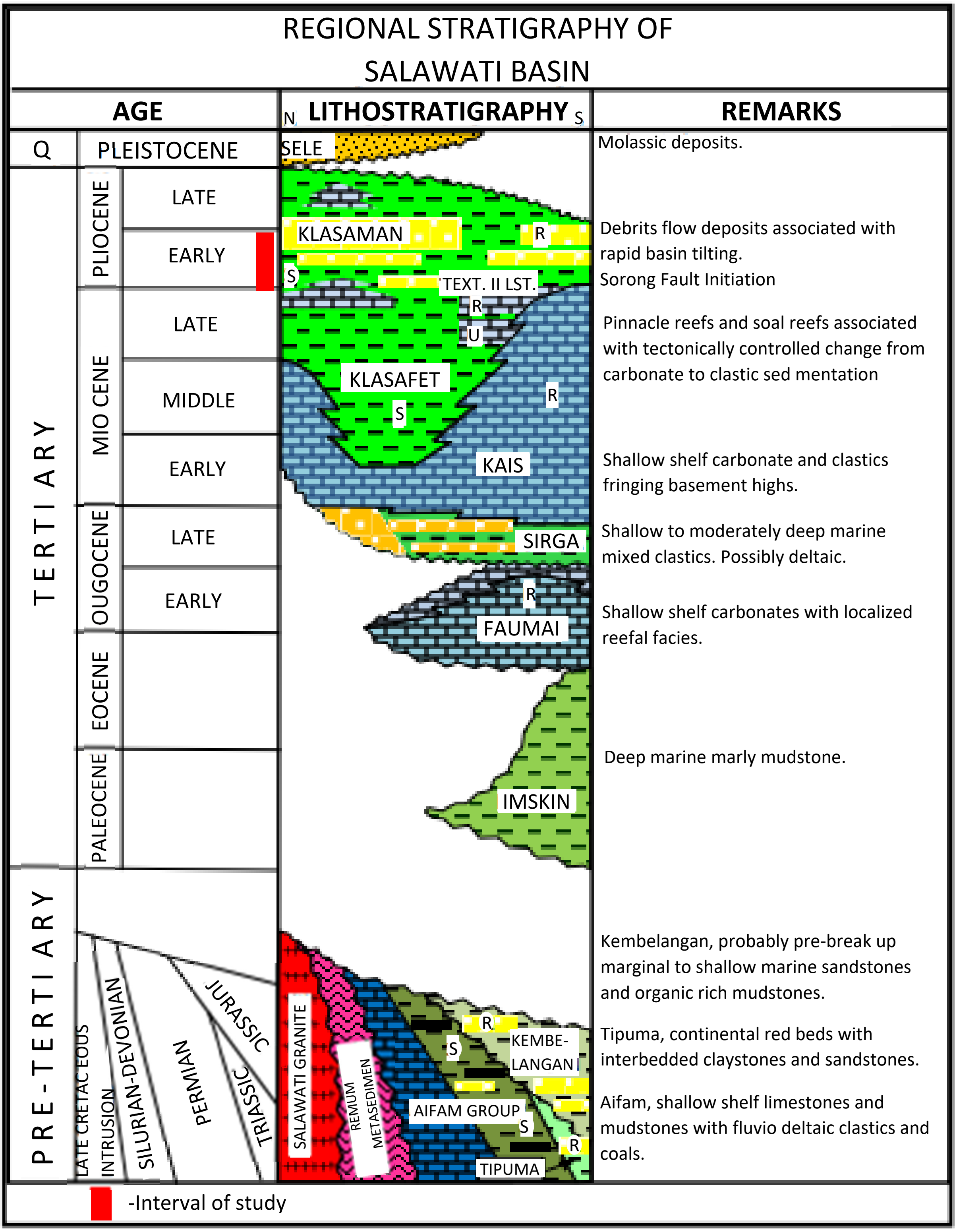
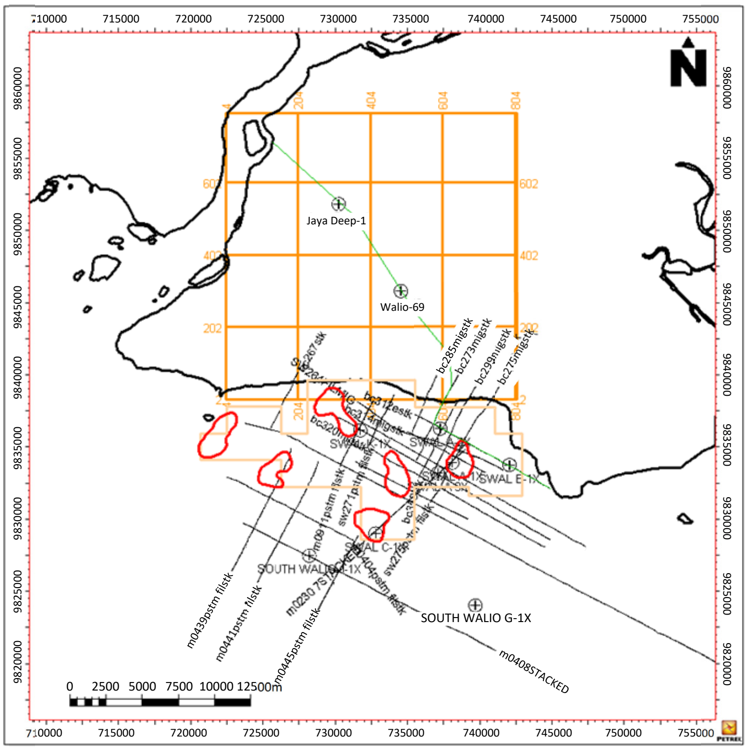


Figure 2
Regional stratigraphy of the Salawati Basin (Satyana 2001)



South Walio Offshore	
North	East
9835947.87	720666.14
9835946.20	722521.27
9837789.44	722522.93
9837786.09	726233.16
9835942.82	726231.47
9835941.11	728086.66
9839627.80	728090.04
9839620.97	735510.98
9838385.74	735520.78
9838393.70	741070.02
9835928.73	741073.29
9835926.91	742928.53
9831625.34	742924.22
9831629.07	739213.73
9832243.50	739214.34
9832247.16	735503.92
9828560.30	735500.27
9828563.98	731789.88
9832250.76	731793.47

Figure 3
The coordinate location map of the study area. The red rectangle plot shows the boundary area of the study.

METHODOLOGY

The methodology in this study includes the analysis of subsurface characterization, velocity and density modeling, and acquisition design parameters evaluation and simulation. First, we build geophysical analysis models using existing 2D data and well-log information. Based on these analysis models, we use both Kais and Waripi Parameter Analysis to calculate and analyze vertical and horizontal resolution, bin size, migration apertures, and maximum offset. Then we use the 2D Modeling module to verify parameters such as bin size, migration aperture, and synthetic records. With this knowledge, we begin the task of calculating the theoretical parameters of the survey.

After establishing the survey's most important theoretical parameters, we continue to determine the source and receiver line spacing. We then define the recording template. It is done by considering 3D bin size, offset limits, and folds.

Second, we examine the two other most important attributes by evaluating and defining several proposed templates for seismic 3D design. They are the offset distribution and the azimuth distribution. It is essential to realize that any 3D survey design is a compromise between technical which affects the cost of a 3D survey from a technical, practical, and logistical objective.

Subsurface structure characterizing

Constructing the structural maps at the beginning of the study needs to be done by making seismic horizon interpretations using existing 2D seismic data. Amplitude balancing needs to be done first for better mapping. This study uses gravity data that is addressed to understand better the possible basement profile. About five horizons were picked in this study, and they are Horizon-1, Kais, Horizon-2, Waripi, and Basement. The time structure map of the five horizons can be seen in Figure 4.

Velocity and density model construction

Following the idea of the previous study (Triyoso et al. 2018), the 3D velocity and density modeling has been carried out by structural modeling based on the five horizons. First, the depth structure map is obtained from the conversion using a velocity based on the gravity model. The detailed workflow to construct the 3D velocity and density model can be seen in Figure 5. Next, the gravity model is used to build the velocity model based on the cross plot between velocity and density based on the gravity model after being adjusted and matched to the density log. The adjusted density based on the gravity data was then applied. Finally, the 3D velocity and density model was constructed based on the structural modeling and converted into depth using the velocity model resulting from the gravity model, as shown in Figure 6.

Time structure map

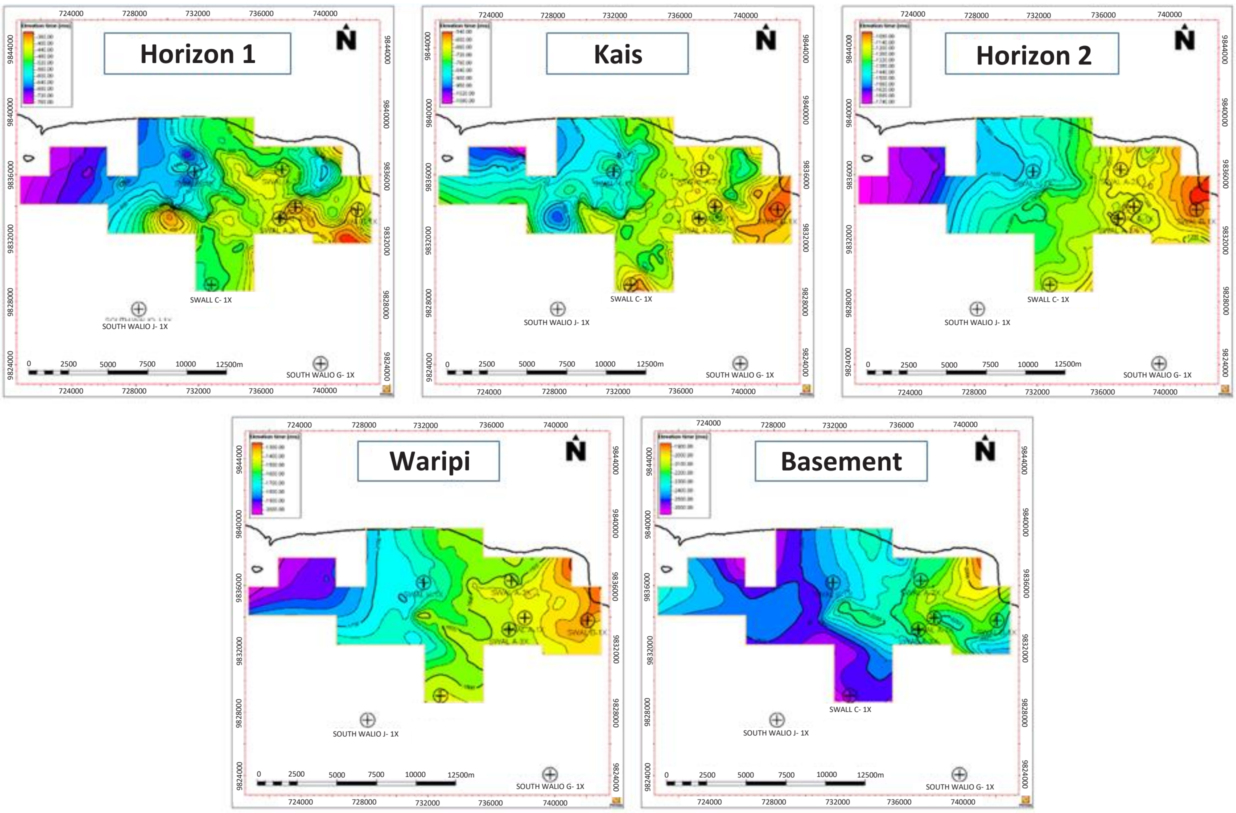


Figure 4
The time structure maps of the five horizons were used to realize the 3D model.

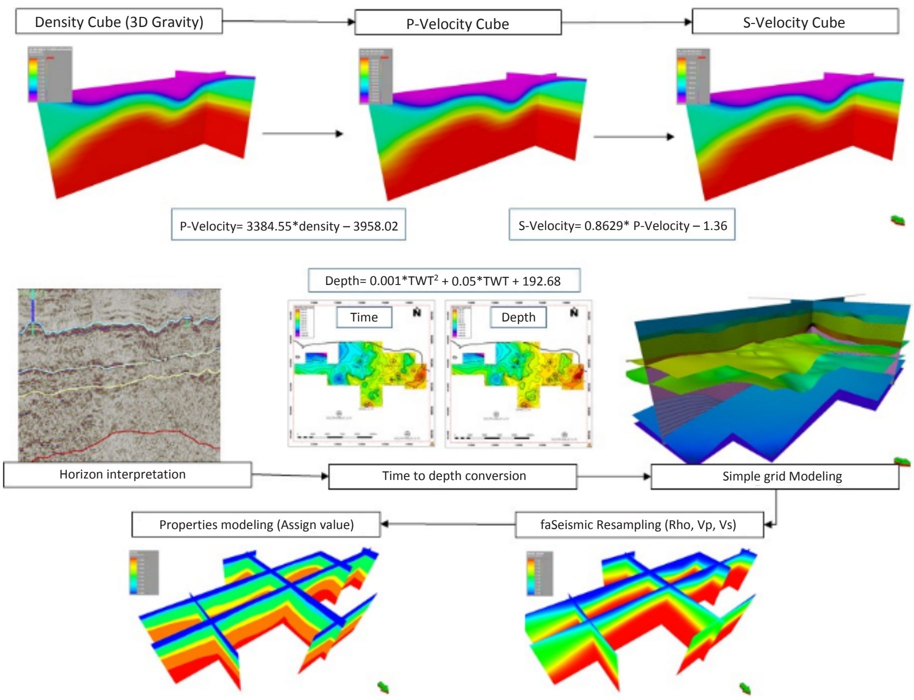


Figure 5
The detailed workflow to construct the 3D velocity and density model

Depth structure map (velocity based on gravity model)

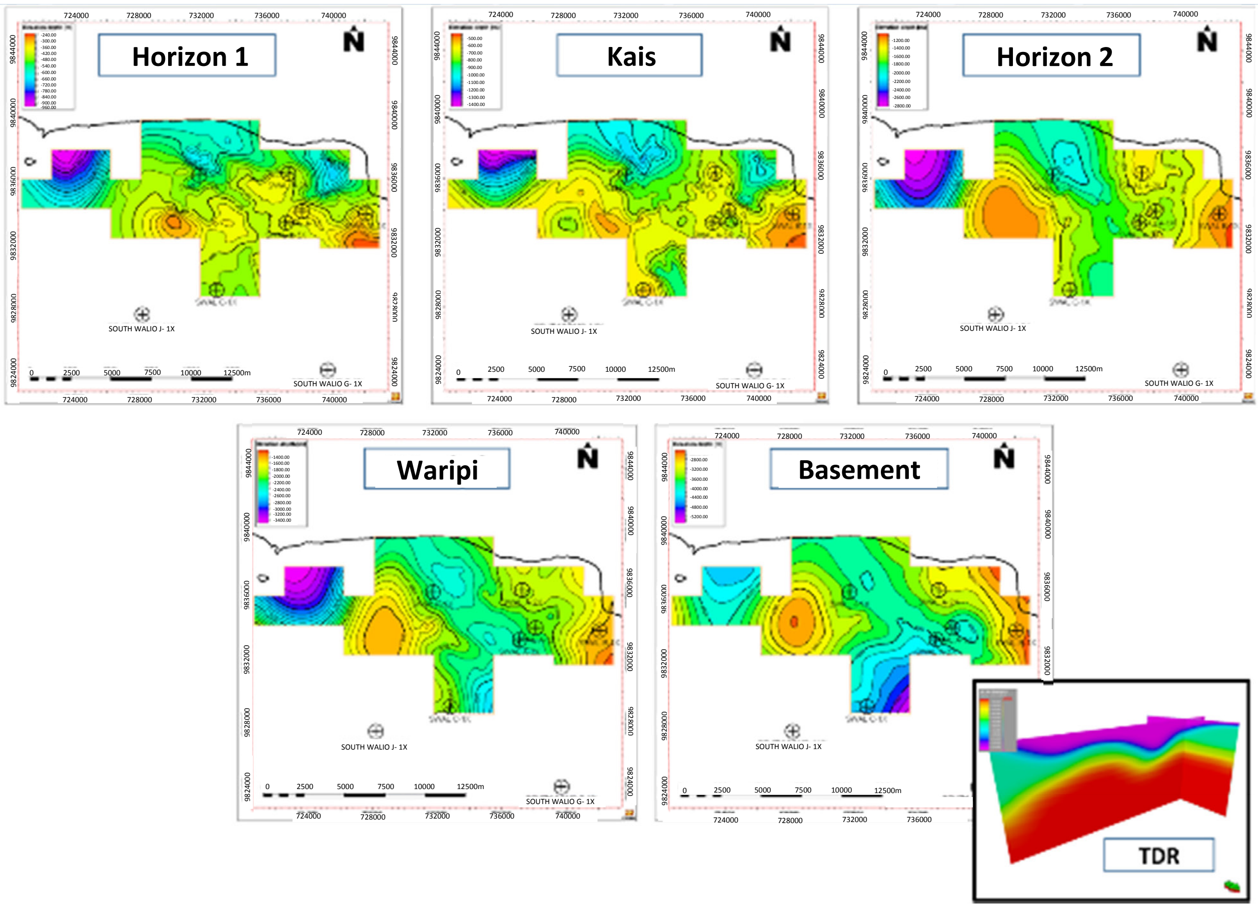


Figure 6
Depth structure of the five horizons.

Acquisition parameter design

In this study, the 3D seismic acquisition parameters design evaluation includes Resolution versus Frequency, Geological & Geophysical Model, Bin Size, Subsurface Target Length, Spatial Aliasing versus Bin Size, and Migration Aperture, Offset, and Mute (Cordsen et al. 2000); (Evans 1997); (Liner & Gobeli 1996); (Liner & Underwood 1999); (Margrave 1997); (Sheriff & Geldart 1989); (Telford, Geldart & Sheriff 1990); (Vermeer 2002).

RESULT AND DISCUSSION

Based on the result of several simulations of the shooting configuration and layout in which the fold coverage, rose diagram and offset distribution are used to get the reliable image of the subsurface model as well as the proposal for the seismic processing that is addressed to have more reliable azimuthal fold coverage could be described as follows.

Seismic survey layout

Static design analysis is carried out to determine how effective the 3D seismic acquisition design has been planned and applied to the survey site boundary. The survey layout planned for this work is shown in the following Figure 7. In this study, we proposed two shooting configurations. They are orthogonal (option 1) and diagonal shooting layout (option 2). The azimuth distribution and offset of the orthogonal and diagonal shooting configuration can be seen in Figure 8.

Receiver	
• Number of RL	: 16, each 8km long
• RL orientation	: E-W
• Total channel	: 2,560 (16 x 160)
• RL interval	: 250 m
• Receiver interval	: 50 m
• Receiver type	: single sensor, Hyd on seabed (& Geo onshore)

Source	
• Source type	: Dynamite min 2kg (airgun > 2000cu.in)
• Source depth	: 25-30m below MSL (note WD < 10m)
• SP interval	: 50 m
• SL interval	: 400 m (EW direction)
• SL orientation	: N-S (orthogonal)

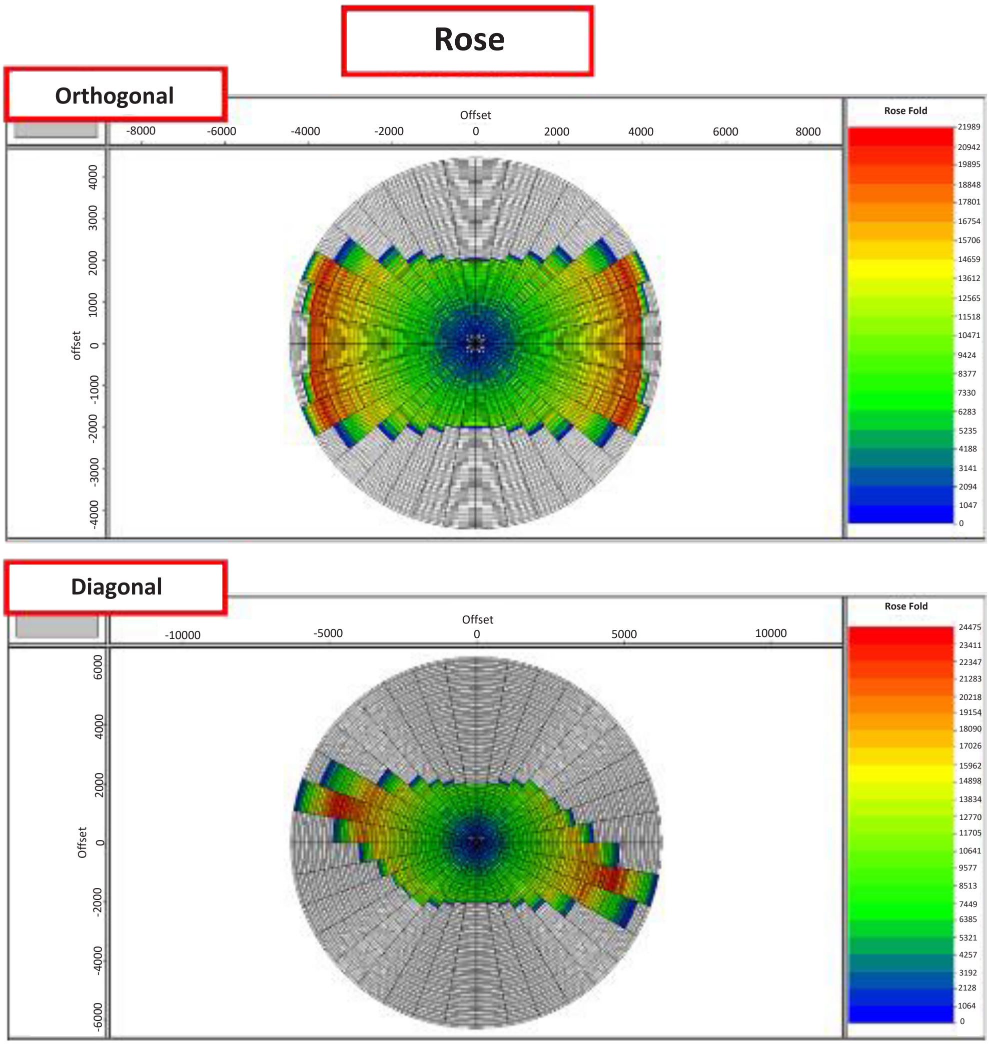
Orthogonal Seismic Shooting configuration (Option 1)

Receiver	
• Number of RL	: 16, each 8km long
• RL orientation	: E-W
• Total channel	: 2,560 (16 x 160)
• RL interval	: 250 m
• Receiver interval	: 50 m
• Receiver type	: single sensor, Hyd on seabed (& Geo onshore)

Source	
• Source type	: Dynamite min 2kg (airgun > 2000cu.in)
• Source depth	: 25-30m below MSL (note WD < 10m)
• SP interval	: 70 m
• SL interval	: 400 m (EW direction)
• SL orientation	: NW-SE (135deg)

Orthogonal Seismic Shooting configuration (Option 2)

Figure 7
The proposal of the two shooting configurations i.e: orthogonal (option 1) and diagonal shooting layout (option 2)



A

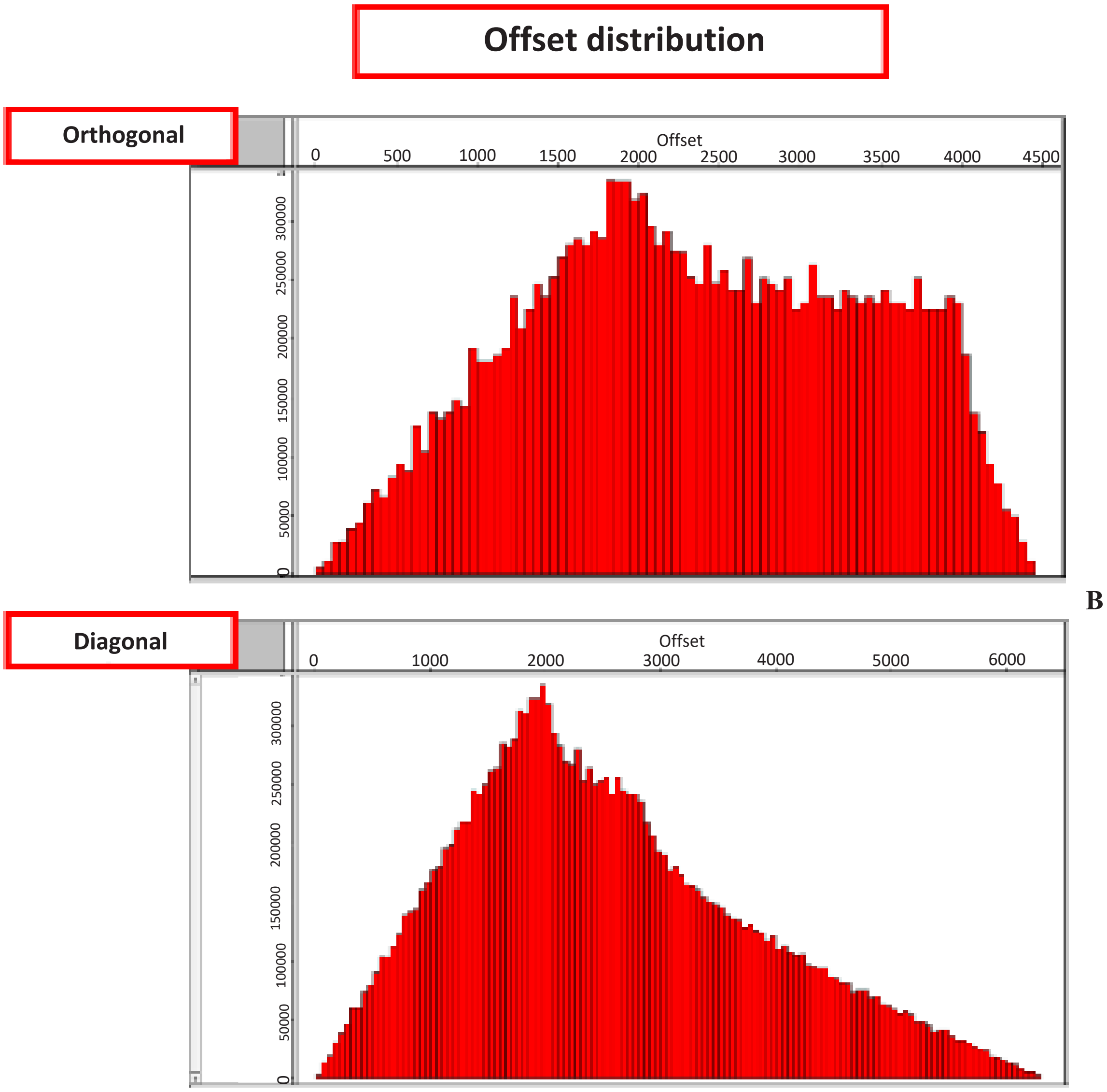


Figure 8
The azimuth distribution and offset of the orthogonal and diagonal shooting configuration

Proposal for the seismic processing sequences

Following the previous study on seismic wave simulation, modeling (Triyoso et al. 2018, 2020) the standard seismic processing for the marine seismic survey (Telford et al. 1990); (Triyoso et al. 2020), the following seismic sequence flow of (Dümmong et al. 2009) and (Muhtar et al. 2021) processing step is then proposed.

PROCESSING SEQUENCES:

01. Reformat
02. Geometry setting
03. Time delay application
04. Bad trace editing
05. Gun/streamer static correction
06. Trace despiking
07. Low-cut filter
08. De-swell noise attenuation
09. Denoise
10. Deghosting
11. Spherical divergence correction
12. Deconvolution
13. 1st Velocity analysis
14. Radon demultiple
15. CRS (Common Reflection Surface)
16. 2nd Velocity analysis
17. Denoise in cdp and offset bin
18. PSTM for velocity analysis
19. 3rd velocity analysis
20. Full PSTM
21. Radon demultiple
22. NMO, mute, and stack
23. Post stack enhancement
24. TVF and TVS

CONCLUSION

Based on the results of this study, we propose two main alternative ideal source-receiver layout models of orthogonal and diagonal and the minimum prerequisites that are expected to map and characterize the shallow and deep target play type models in the South Walio Offshore area:

- It is recommended to use the orthogonal static design layout, which has a more prosperous or wider azimuth distribution and a relatively more uniform offset distribution. The bin size is 25m x 25m.
- The realization of the water-bottom data in this study is still based on free domain data; therefore, to ensure and validate the composition of the shot type and its quantity, it is necessary to conduct a bathymetry survey prior to seismic acquisition.
- The standard seismic processing flow is also proposed in this study. In addition, we add the Common Reflection Surface as an optional seismic processing flow that could be added to enhance the quality in case the lowest fold coverage acquisition geometry is preferred.

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GLOSSARY OF TERMS

Symbol	Definition
DHI	Direct Hydrocarbon Indicator
CRS	Common Reflection Surface
PSTM	Pre-stack Time Migration
NMO	Normal Move Out

REFERENCES

Babu, N.M., Baskey, B., Thota, V.G., 2022, Evaluation of 3D seismic survey design parameters through ray-trace modeling and seismic illumination studies: a case study. J Petrol Explor Prod Technol 12, 3021–3031 (2022).

Cordsen, A., Galbraith, M., Peirce, J., 2000, Planning land 3-D seismic surveys, Soc. Expl. Geophys., Tulsa, Oklahoma**.**

Dümmong, S., Baykulov, M., Dirk Gajewski, D., 2009, "A workflow for the processing of reflection seismic data with CRS attributes," *SEG Technical Program Expanded Abstracts* **: 3173-3177.**

Doust, H. & Noble, R., 2008, Petroleum systems of Indonesia. Marine and Petroleum Geology - MAR PETROL GEOL. 25. 103-129. 10.1016/j.marpetgeo.2007.05.007.

Evans, B. J., 1997, A handbook for seismic data acquisition: Soc. Expl. Geophys., Tulsa, Oklahoma.

Liner, C. L. & Gobeli, R., 1996, Bin size and linear v(z): 67th Ann. Internat. Mtg., Soc. Expl. Geophys, Expanded Abstracts, 43-46.

Liner, C. L., Underwood, W. D., 1999, 3-D seismic survey design for linear V(z) media: Geophysics, 64, 486-493.

Margrave, G. F., 1997, Seismic acquisition parameter considerations for a linear velocity medium: 67th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 47-50.

Moldoveanu, N., Lee, K.S., Jorgensen, P., 2003, Onboard 3D & 4D subsurface target illumination: A tool to optimize streamer marine acquisition. In: SEG Technical Program Expanded Abstracts, 2003. Society of Exploration Geophysicists, pp 4–7.

Muhtar, L.K., Triyoso, W., Fatkhan, 2021, Application of common reflection surface (CRS) to velocity variation with azimuth (VVA_z) inversion of the relatively narrow azimuth 3D seismic land data. Open Physics 2021; 19: 439–446.

Ovinda, Sunardi, E., Hamdani, A.H., Burhannudinnur, M., Triwerdhana, A. 2018, Facies and Sequence Stratigraphy Analyses of Klasaman Formation in the "X Well," Northern Salawati Basin, Papua, Indonesia. Open Journal of Geology, 8, 499-513.

Rijks, E. J. H., Jauffred, J. C. E. M., 1991, "Attribute extraction: An important application in any detailed 3-D interpretation study," *The Leading Edge* **10: 11-19.**

Satyana, A.H., 2001, Identifying New Petroleum System of the Salawati Basin, West Papua: Exploration Opportunities in Mature Basin. Lomba Karya Tulis EP II Pertamina, 2001.

Sheriff, R.E. & Geldart, L.P., 1989, "Exploration seismology volume 1: History, theory, and data acquisition, Cambridge University Press, 1989.

Stork, C., 2011, Seismic acquisition is moving from a " CMP Fold " perspective to a " Wavefield Recording " perspective which has significant implications on acquisition design. In: SEG technical program expanded abstracts 2011. Society of Exploration Geophysicists, pp 157–162.

Telford, W. M., Geldart, L. P. & Sheriff, R. E., 1990, Applied geophysics, 2nd ed: Cambridge Univ. Press.

Triyoso, W., Oktariena, M., Muhtar, L. K., 2018, Ray-Binning Angle Stack Domain in Enhancing the Robustness of Converted-Wave Seismic Joint Inversion, Scientific Contributions Oil and Gas Vol. 41, No 3, 2018.

Triyoso, W., Irawan, J. B., Viony, N. C., Fatkhan, 2020, Application of ZO-CRS Stack on Residual PP Removal of PS Component in Converted-Wave Seismic Reflection Processing, Scientific Contributions Oil and Gas Journal, Vol. 43 No 2, 2020.

Vermeer, G. J. O., 2002, 3-D seismic survey design, Soc. Expl. Geophys., Tulsa, Oklahoma.