IATMI22-069

Stages of Quality Control of Low Frequency Passive Seismic Data Acquisition: study case of NL area Sangasanga Field

Ferdi Rizal [*1], C. W. Wicaksono[2], Endra Triyana[3], Soni Satiawan[4], and Dicky Ahmad Zaky[5]
[1] Pertamina Hulu Indonesia, [2,3] SKK MIGAS, [4,5] Universitas Pertamina
* Email: ferdi.rizal@pertamina.com

Abstract. In January 2022, passive seismic data acquisition using a three-component broadband seismometer was successfully completed at the NL area Sangasanga field. Commonly, LFPS acquisition uses surface seismometers equipment but in this study borehole seismometers were utilized to acquire the data at all stations planned. It was a challenging condition in the middle of active production of open pit mining (24 hours a day, 7 days a week). Some strategies of acquisition have been made to deal with surface noise (human activities) to ensure the quality of data prior to advanced data processing. Due to the usage of borehole seismometers thus the procedure in equipment deployment should be cleared and recorded in data acquisition particularly, azimuth or orientation of sensor, coupling sensor and level of sensor. Moreover, the quality control or daily data acquisition checking is also to be done including daily calibration, visual/ qualitative analysis of recorded data and polarization analysis. The classification of recorded data could be achieved after the three stages of quality checking were performed. The classification into three classes based on the length of good data from recorded data, result of polarization analysis, as well as the consistency of value in daily data calibration. From each analysis of data classification obtained that the repetition measurement was needed in several points and the analysis is expanded to VHSR analysis to tackle the dips results from polarization issues. Therefore, the result of this study is VHSR map and utilized to determine a new drilling proposed well VHSR value is higher than 0.3 is indicated as the hydrocarbon prospect. In addition, result of the delineation hydrocarbon prospect map from this study is quietly matched with the net sand map of the study area that was built from various data integrations.

Keyword(s): Passive seismic; borehole seismometer; challenge environment; improvement on qc process.

1 Introduction

The NL area is situated inside Sangasanga field – a mature onshore oil field in Kutei basin which operated by Pertamina EP Asset 5 since 2008 until end of PSC license in 2035. The NL area has coverage 33.5 Km^2 (~ 8 km x 4 km), it is bounded by Pertamina Hulu Sanga Sanga (PHSS) in the northern (Lampake field) and eastern side (Nilam field). The area was discovered by NIMH (Dutch oil company) in 1897 and continue to operate with several companies, including Japan while invaded in 1942-1945, World Ward II.

In terms of subsurface, this NL area is located in the crestal of anticlinorium SangaSanga where plunged towards north to the Lampake field. Stratigraphically, it is consisted of fluvial to lower delta plain of depositional environment with thickness range from 8 to 15m. The 3D seismic was performed by Medco while operated this area as Technical Assistant Contract terms (TAC) in 1998. After several reprocessing of 3D seismic – latest in 2010, it still could not resolve any potential hydrocarbon in the east flank of northern NL area where single reservoir target of D-10 layer as one of oil major contributor is located (figure 1).

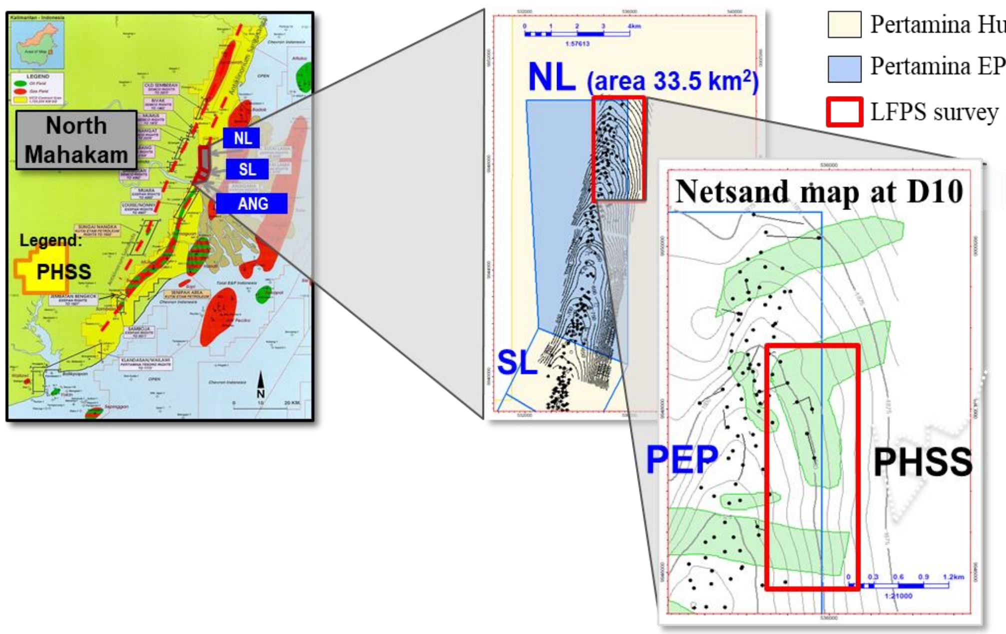


Figure 1. Location map of study area (NL Area, Sangasanga field, Onshore Kutai Basin).

1.1 Problem Statement

The D-10 layer at east flank has initially idenfitifed as a big oil tank from post drill results of NL-1063 on August 2014 with Qoi 731 bopd from 15m of oil bearing reservoir. Uniquely, the channel trend of this tank is north to south direction which is different from global channel trend, west to east direction. The north-south trend was confirmed by the last two drilled wells in 2021 where still producing oil with rate 340 bopd and 240 bopd and 0.1% water cut respectively, as per October 2022. It becomes a challenge to have development scenario since no reference wells at the southern of last drilled wells and 3D seismic could not resolves the sand extension. Meanwhile, it close to another water fluvial channel with west-east direction where located updip and SW of last drilled D10 wells which remains uncertainty the extension of north – south channel direction (figure 2).

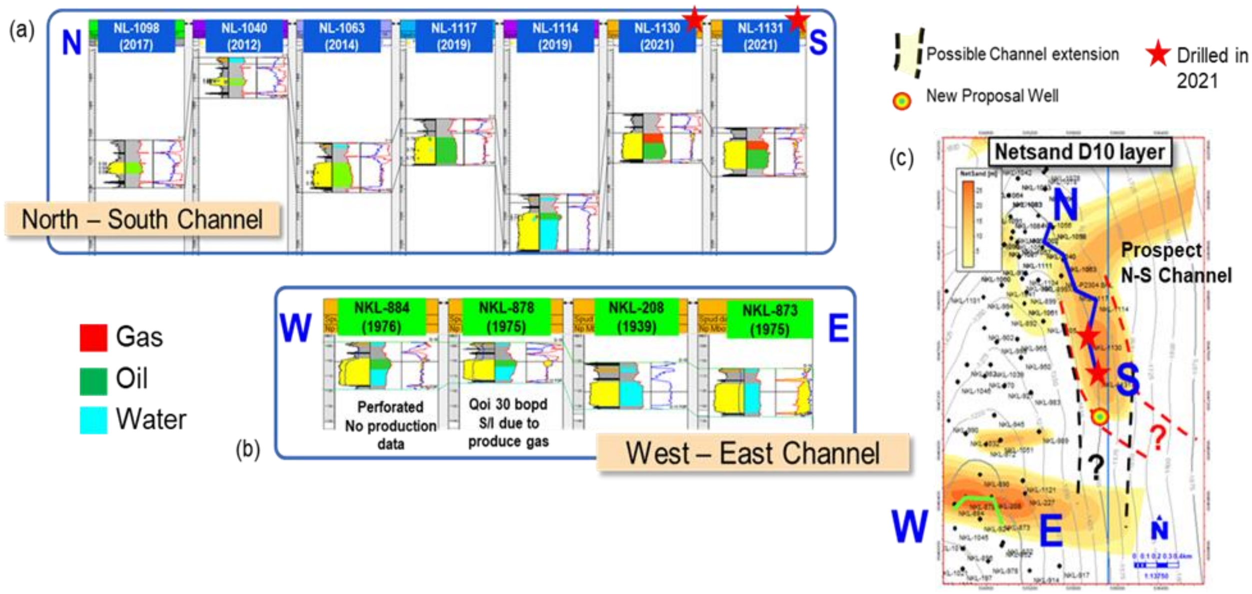


Figure 2. Distribution of netsand in D10 layer of east flank (a) N-S prospect channel trend (b). W-E channel trend, more updip than N-S channel and already water out (c) Disconnectivity between those two channels. Which direction the exension of HC prospect N-S channel will be ?

1.2 Objective

The Low Frequency Passive Seismic (LFPS) method is a relatively new geophysical technology for hydrocarbon reservoir detection and monitoring or well known as direct hydrocarbon indicator (DHI) especially in several Pertamina oil field. Its method is the fastest solution, low operational cost and environmentally friendly due to no utilization artificial sources. This method had been acquired in 2018 at NL area however unfortunately the area of acquisition did not cover the east flank of D10 layer. The chosen of low frequency passive seismic method with borehole equipment is to solve the surface noise due to the busy activities of open pit coal mining in the surface.

2 Methodology

2.1 Low Frequency Passive Seismic (LFPS)

The development and utilization of LFPS methods on hydrocarbon exploration were quite massive in the past decades. The phenomenon was observed on previous studies (Dangel et al, 2003, Ali et al., 2007, Saenger et al, 2007) showed that the LFPS response of reservoir containing hydrocarbon is distinct compared to non-hydrocarbon sites (figure 3). The acquired data is passive seismic background noise measured on the surface using seismometer, then the spectrum signal is observed on low frequency band between 1 – 5 Hz. Subsequently, the maximum amplitude spectrum of vertical component was observed as response of hydrocarbon sites (Dangel et al, 2003).

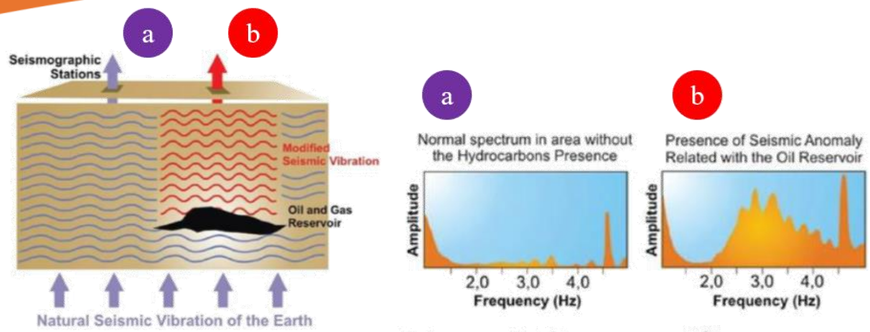


Figure 3. Illustration of background noise frequency response on the non-hydrocarbon site (a) and hydrocarbon site (b).

2.2 LFPS Data Acquisition

Borehole seismometer with three component is used in this study with broadband frequency response within range 0.1 – 98 Hz. The set instrument of seismometer is equipped with digitizer, GPS, battery, etc (figure 4a). The deployment of borehole seismometer is described on figure 4. The borehole unit was put in 1 meter depth hole and cased by PVC pipe. The sensor then hoards with sand and water to maximize sensor coupling. The recording takes places within 2 – 3 hours for each station.

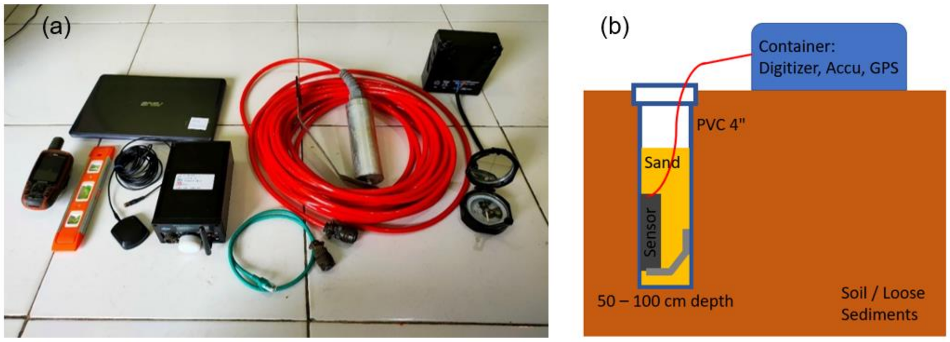


Figure 4. (a) Set of instrument borehole seismometer and (b) Schematic diagram of borehole unit deployment.

2.3 Polarization Analysis

The seismometer was measuring seismic signal on three-component which is vertical component (z-axis), east component (x-axis) and north component (y-axis). Then by plotting all these three-component data in 3D space we will have the illustration of particle motion (figure 5). Moreover, polarization of the particle motion along the recording trace could be calculated by applying moving window then solving the eigen value and eigen vector from the auto and cross variance matrix (Jurkevics, 1988).

There are four attribute that describe the polarization of the particle motion as follows,

- Azimuth (θ): polarization angle on horizontal plane from source to receiver measured from north.
- Dip (ϕ): polarization angle on vertical plane from source to receiver measured from horizontal plane.
- Planarity: quality of ellipse polarized into a plane.
- Rectilinearity: quality of ellipse polarized into 1D linear stripe.

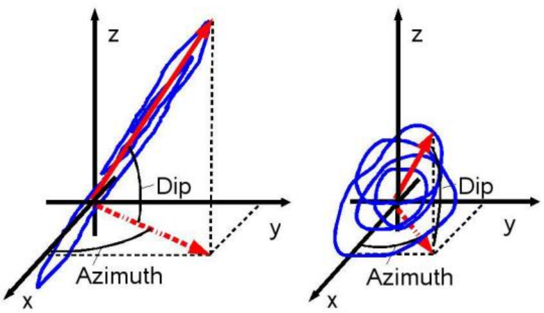
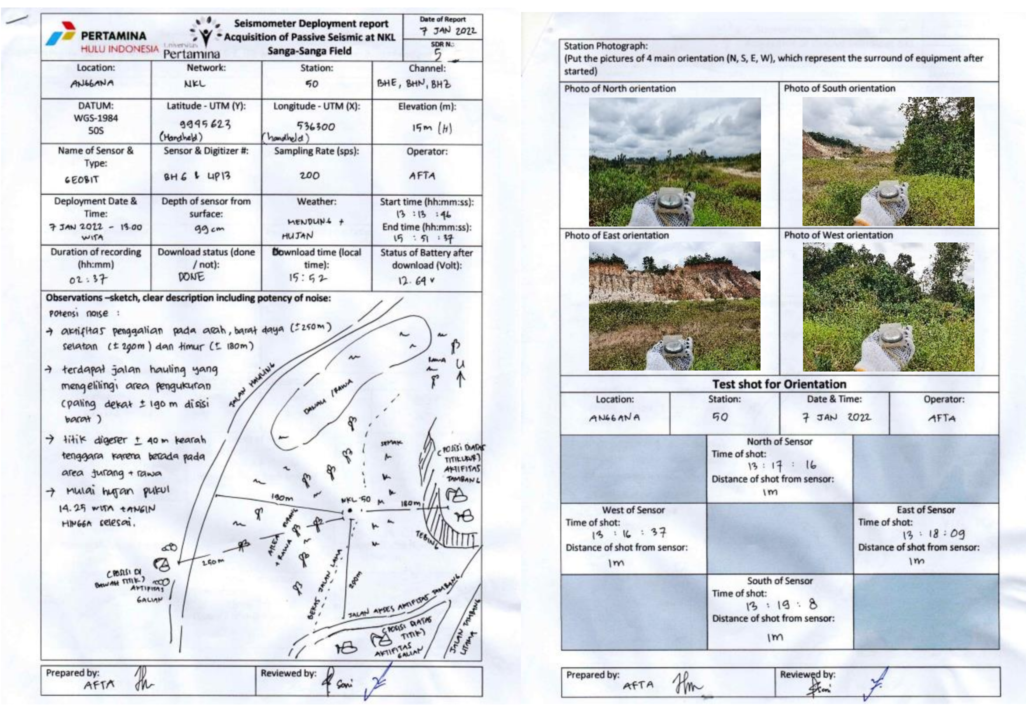


Figure 5. Polarization attribute of particle motion, on the left is medium dip and high rectilinearity the on the right is low rectilinearity with relatively high dip. (Saenger et al., 2017).

3 Results & Discussion

3.1 Preprocessing of Data Acquisition

There are 84 of data acquisition was successfully recorded from this study, consisted of 50 of data planning, 10 of reference well of data planning, and 24 of data repetition. All of seismometer deployment was recorded in every data station in a Seismometer Deployment Report (SDR) to ensure and ease the data quality control as seen in figure 6. SDR is not only used in quality data checking but also used to verify the result of data processing particular in ensuring the data chosen instead of noise. Analysis visually is the first step to know the quality of qualitatively. Figure 7 is an example of data visualization from the field that show the bad quality of data which is marked by the significant spiky signal in all data recording (dash red line).



PERTAMINA HULU INDONESIA — Universitas Pertamina
Seismometer Deployment report
Acquisition of Passive Seismic at NKL
Sanga-Sanga Field

Date of Report: 7 JAN 2022
SDR No: 5

Location:	Network:	Station:	Channel:
ANGGANA	NKL	50	BHE, BHN, BHZ
DATUM: WGS-1984 50S	Latitude - UTM (Y): 9995623 (Handheld)	Longitude - UTM (X): 536300 (handheld)	Elevation (m): 15m (H)
Name of Sensor & Type: GEOBIT	Sensor & Digitizer #: BH6 & UP13	Sampling Rate (sps): 200	Operator: AFTA
Deployment Date & Time: 7 JAN 2022 - 13.00 WITA	Depth of sensor from surface: 99 cm	Weather: MENDUNG + HUJAN	Start time (hh:mm:ss): 13 : 13 : 46 End time (hh:mm:ss): 15 : 51 : 37
Duration of recording (hh:mm) 02 : 37	Download status (done / not): DONE	Download time (local time): 15 : 52	Status of Battery after download (Volt): 12.64 v

Observations –sketch, clear description including potency of noise:
Potensi noise :
→ aktifitas penggalian pada arah, barat daya (±250m) selatan (± 290m) dan timur (± 180m)
→ terdapat jalan hauling yang mengelilingi area pengukuran (paling dekat ± 190 m disisi barat)
→ titik digeser ± 40 m kearah tenggara karena berada pada area jurang + rawa
→ mulai hujan pukul 14.25 WITA + ANGIN HINGGA selesai.

Prepared by: AFTA
Reviewed by: Soni

Station Photograph:
(Put the pictures of 4 main orientation (N, S, E, W), which represent the surround of equipment after started)

Photo of North orientation | Photo of South orientation
Photo of East orientation | Photo of West orientation

Test shot for Orientation

Location:	Station:	Date & Time:	Operator:
ANGGANA	50	7 JAN 2022	AFTA

North of Sensor — Time of shot: 13 : 17 : 16 — Distance of shot from sensor: 1m
West of Sensor — Time of shot: 13 : 16 : 37 — Distance of shot from sensor: 1m
East of Sensor — Time of shot: 13 : 18 : 09 — Distance of shot from sensor: 1m
South of Sensor — Time of shot: 13 : 19 : 8 — Distance of shot from sensor: 1m

Prepared by: AFTA
Reviewed by:

Figure 6. An example of Seismometer Deployment Report which is provided the information during equipment installation and data recording. This SDR is part of 1st QC steps.

In addition of data visualization, polarization analysis was an advance processing step that should be carried out to ensure the quality of data. Four parameters from this analysis should be obtained and determine to classify the quality of data as seen on figure 7. From this analysis to all data is obtained that azimuth, planarity and rectilinearity parameters is considered in fulfilling the quality control’s stage however in incidence angle parameter show that the domination of horizontal signal. The domination of horizontal signal can be interpreted as the data contains surface noise a lot and weaken the vertical signal. Thus, advance processing is necessary to gain the vertical response and vertical to horizontal signal ratio is one of method to enhance the vertical response and minimize the horizontal response.

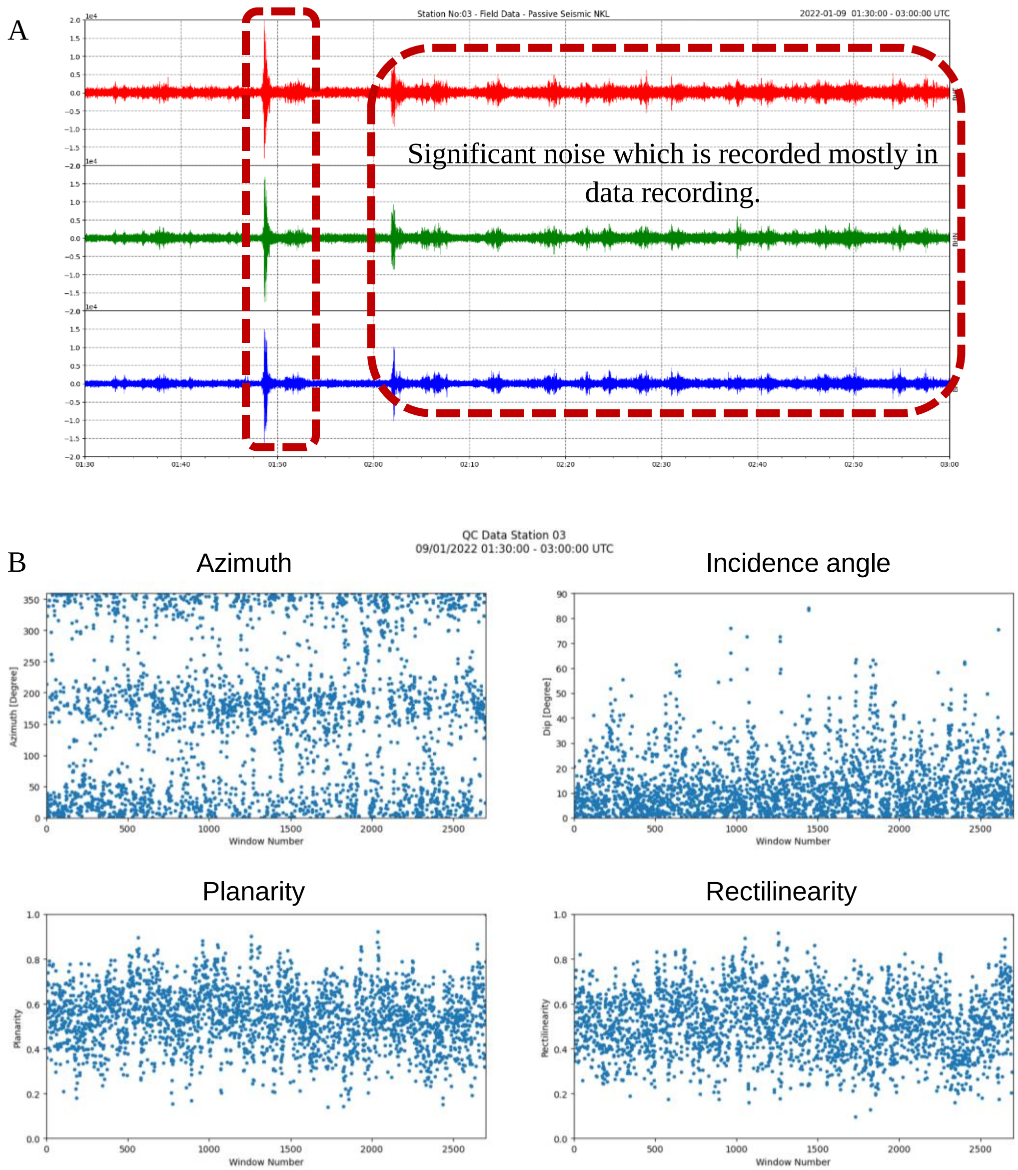


Figure 7. Data visualization (A) and polarization analysis (B) of station 03 show the bad quality data and repetition acquisition is a must in this station. The figure a & b is part of 2nd and 3rd QC steps.

3.2 Results of Data Processing

Each stage and integrated analysis of all result from data quality control influence the stage in data processing including in advance processing (figure 8). In this study, VHSR is an attribute in data interpretation to delineate the hydrocarbon prospect as well as in determine the new proposed well (NL-P2103). Based on the comparison between the field data (repetition data in 24 stations) and data from 10 of well reference is obtained that the VHSR value which represents the hydrocarbon indicator is higher than 0.3 (figure 9). Moreover, the result of VHSR map, which is obtained from data processing, coincidentally is quietly match with the netsand map. Therefore, VHSR map obtained from passive seismic data analysis is able to be used for the next step particularly in determining the new proposed well for field development matter (figure 10) as well as adjustment on the netsand map direction. According to the result of this new proposed well (NL-P2103) which already drilled on September 2022. It showed the well has proven 8m of oil (actual was less than prognosis, 13 meter). The result of LFPS brings more confidence to use it as an alternative solution as direct hydrocarbon indicator (DHI) and derisking new well placement.

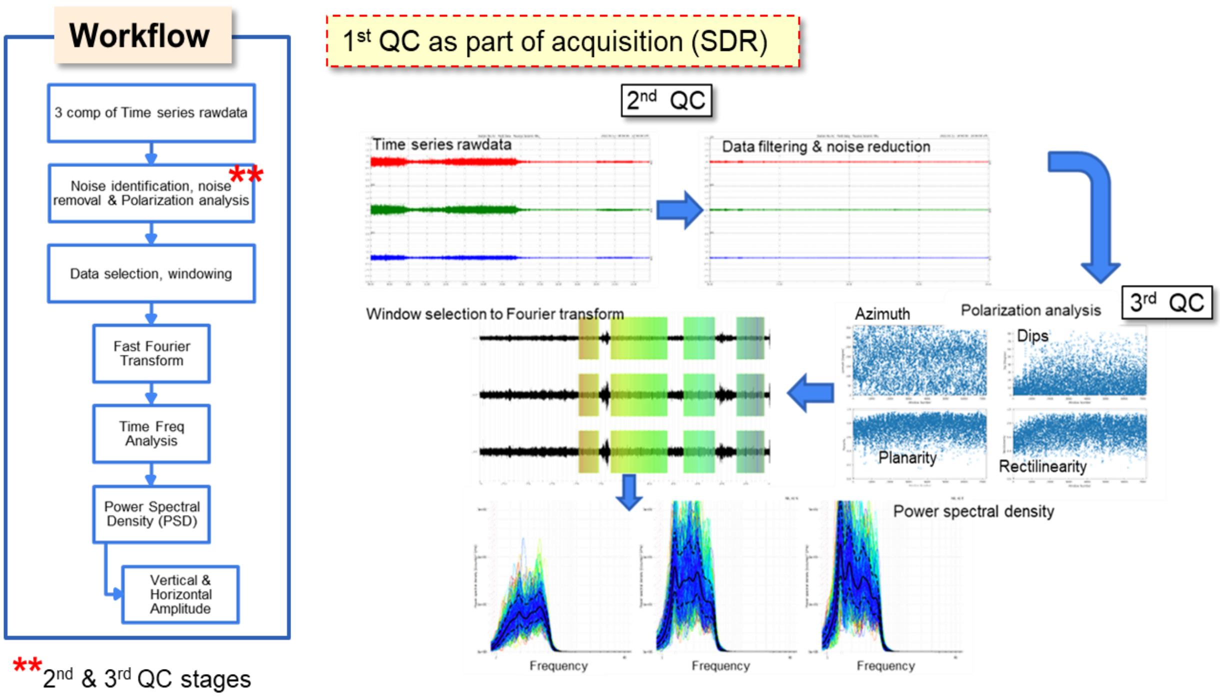
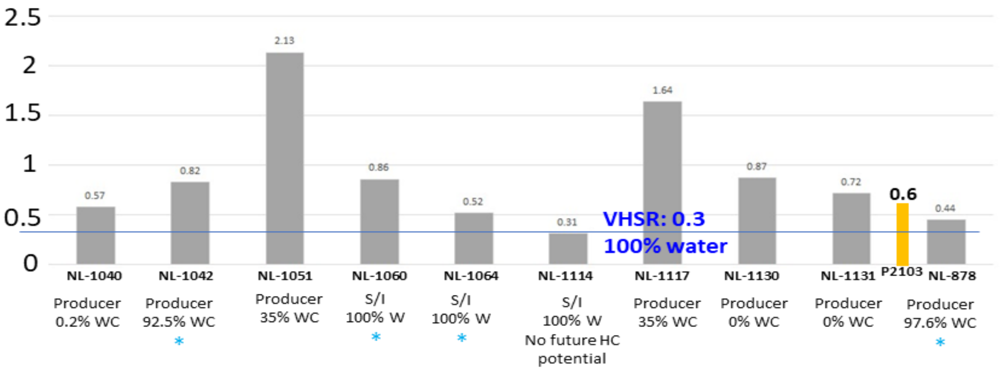


Figure 8. The workflow of LFPS processing which integrated with 2nd and 3rd QC stages, meanwhile 1st QC stage was performed while acquisition as seismometer deployment report (SDR).



*wells with high WC (water cut) but still has future HC potential (NL-1060, NL-1042, NL-878)

Figure 9. VHSR value of ten reference wells to determine HC cut off. The VHSR value of new proposed well (NL-P2103) is 0.6, above cut off as potential hydrocarbon (HC).

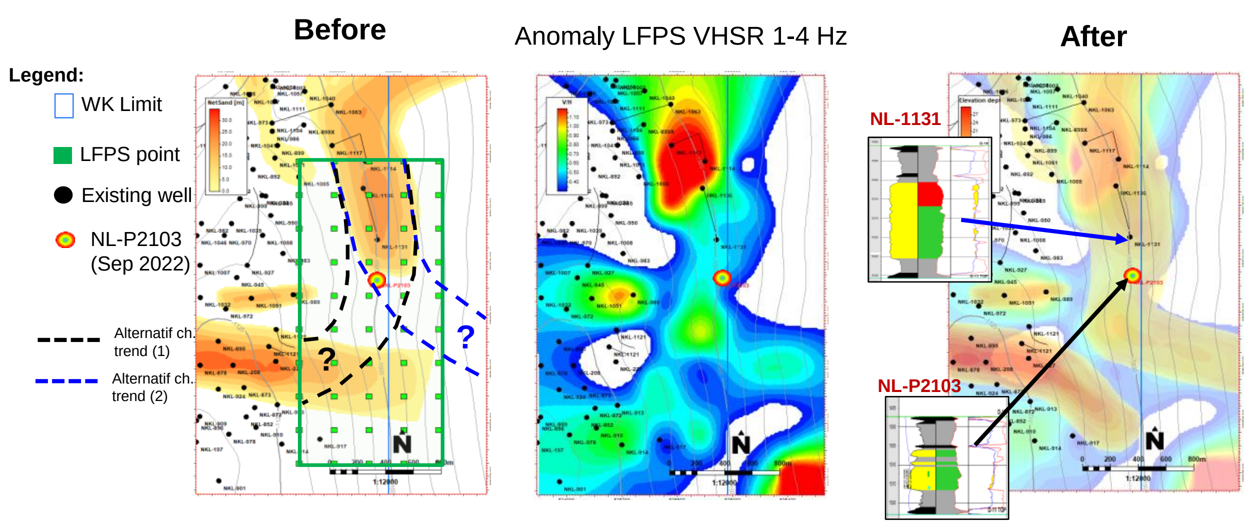


Figure 10. Before LFPS acquisition, channel trend of D10 layer has two uncertainties between westward (black dash line) and eastward (blue dash line). According to the anomaly LFPS VHSR 1-4 Hz, the trend of anomaly VHSR similar direction to the eastward thus netsand map has adjusted. The result of NL-P2103 was drilled on Sep 2022, it proves anomaly LFPS could be used as direct hydrocarbon indicator.

4 Conclusion

Data QC plays an important role in data processing and data interpretation. Three stages of QC should be carried out to ensure the quality of the data, including examining the field report, data visualization, and polarization analysis. It is also time-efficient to have a decision on whether to re-measure or continue to the next data processing step. Moreover, the advanced processing can also be determined from this analysis, such as the VHSR analysis, which was performed in this study. The final result from data QC, data processing, and advanced processing shows that the VHSR value that is correlated with HC prospect is higher than 0.3. The location of the new proposed well has a VHSR value of 0.6 and the N-S channel is still continuing in the south-east direction. The post-drill result of the new proposed well, which was drilled in September 2022, shows proven 8m of oil (prognosis 13m). As a result, LFPS proves as a direct hydrocarbon indicator (DHI). Since the method is environmentally friendly, low operational cost and quick time for acquisition and processing thus, LFPS could be used as an alternative method to help future development strategy in step out area and mature field.

Acknowledgments

We would like to express our gratitude and appreciation to the management of PT. Pertamina Hulu Indonesia Zona 9 and SKK MIGAS for kind permission to publish this paper.

References

[1] Ali, M.Y, Berteussen, K.A., Small, J. and Barkat, B., 2007, “A low frequency, passive seismic experiment over a carbonate reservoir in Abu Dhabi”, First Break 25 pp 71-73.

[2] Dangel, S., M. E. Shaepman, E. P. Stoll, R. Carniel, O. Barzandji, E.-D.Rode, and J. M. Singer., 2003, “Phenomenology of tremor-like signals observed over hydrocarbon reservoirs”, J. Volcanol. Geothermal Res., 128, 135–158.

[3] Jurkevics, A., 1988, “Polarization Analysis of Three-Component Array Data”, Bulletin of the Seismological Society of America, 78, 1725-1743.

[4] Saenger, E.H., Torres, A., Rentsch, S., Lambert, M., and Schmalholz, S.M., 2007, “A Hydrocarbon Microtremor Survey Over A Gas Field: Identification Of Seismic Attributes”, 76th SEG Annual Meeting, Expanded Abstracts, 1277–1281.