Utilization of Bathymetry Data and Backscatter in Geohazard Identification Process at Drilling Stage

Irena Hana Hariyanto[1*], *Khomsin[1]*, *I* Nyoman Dimas Adhi[2], *Anggara* Rachmat[2], and *Kayla* Rashieka Noer[1]

[1] Geomatics Engineering Department, Institut Teknologi Sepuluh Nopember, 60111 Surabaya, Indonesia
[2] Pertamina Hulu Energi Offshore Southeast Sumatera (PHE OSES), Indonesia

Abstract. The Indonesian people's need for energy supply has increased in recent years, and hydrocarbon production has been intensified to meet these needs. Exploration on land or at sea is not an obstacle to obtaining the hydrocarbons sought; both are subject to the presence of geohazards. This study was conducted to determine the seabed features conditions that potentially become geohazards and to provide recommendations for the jack-up rig line selection. The purpose of this research is, in line with the Sustainable Development Goals, to prevent and significantly reduce marine pollution of all kinds. The acoustic instruments used were Single Beam Echosounder, Multibeam Echosounder, and Side Scan Sonar. The seabed depth varied from 22-23.9 m with a nearly flat morphology and local slope of 0°-2°. The main features identified include exposed pipes, jack-up rig footprints, a spud-can drag scar, and a seabed scar. The sediment distribution showed a predominance of soft-textured clay. Using the weighting combined with the slope value and the presence of geohazard potential features, it is recommended that the jack-up rig enter through the Northeast-East side of the platform to improve operational safety and reduce potential accidents such as exposed pipelines and subsea cables and clusters of seabed scars.

1 Introduction

The importance of energy supply for human life is becoming increasingly apparent. Humans certainly need adequate energy sources to support their daily activities, including economic, industrial, and social activities. Energy sources such as oil and gas, coal, and renewable energy are the main drivers of supporting human activities. In Indonesia, the demand for energy supplies has also increased in recent years. The consumption of energy

*Corresponding author: irena@its.ac.id

supply in Indonesia increased by 19%, from 1,462 million barrels of oil equivalent (BOE) in 2021 to 1,739 million BOE in 2022. The percentage of energy supply in 2022 consisted of 42.38% coal, 31.40% oil, 13.92% gas, and 12.30% renewable energy [1]. Those energy potentials, particularly the oil and gas industry, need to be mapped to support the existence of Sustainable Development Goals (SDGs) about Life Below Water to prevent and reduce marine pollution of all kinds.

Oil and natural gas, also known as hydrocarbon energy, occupy the second and third positions, respectively, in the energy supply needed to support the daily life sector. The hydrocarbon production process is intensified to meet the increasing demand. Location is no barrier to the exploration and exploitation of wells to obtain the hydrocarbons that are sought. On land or at sea, neither is it exempt from the presence of geohazards. The hydrocarbon extraction process at sea is carried out by drilling in a platform assisted by a rig, the type of rig in question being the jack-up rig.

Before the jack-up rig enters the platform, a geohazard survey consisting of geophysical and geotechnical surveys is conducted. Geohazard or geological hazard is defined as a geological process that poses a threat to the safety of life and material [2]. Both surveys were conducted to determine information related to potential geological hazards that could hinder the main activities and other activities in the vicinity of the platform area. A geophysical survey was conducted to review and collect information on potential geological hazards, such as the presence of surface and sub-surface features of the seabed, such as pockmarks, seabed gas pipes, and so on, that could hinder the jack-up rig's entry to the platform. In contrast, geotechnical surveys review and collect information on potential geological hazards based on the mechanical and geotechnical properties of soil and seabed rocks [3].

Therefore, a geohazard survey is needed to anticipate threats such as changes in the structure of the jack-up rig [4], land shifts [5], and other potential hazards that can disrupt and endanger. This research was conducted in the Southeast waters of South Sumatra Province and focused on the geohazard from the geophysical survey side using three water acoustic measurement instruments namely, Single Beam Echosounder, Multibeam Echosounder, and Side Scan Sonar.

These three tools obtain the results of the final report along with suggestions. The Single Beam Echosounder (SBES) was chosen for its reliability, accuracy, and cost-effectiveness in measuring seabed depth, making it ideal for identifying potential hazards like pockmarks and uneven surfaces. Its simplicity and suitability for initial site assessments, combined with complementary tools like Multibeam Echosounder (MBES) and Side Scan Sonar (SSS), provide a comprehensive and robust geohazard analysis. Therefore, it can be used as a consideration for the jack-up rig entry path selection to the platform when intending to carry out offshore drilling. In addition, it can also be used to manage geohazards at the site to reduce the potential for accidents, such as shallow blowouts.

2 Method

The study was conducted in the southeast of South Sumatra Province. The details of the case study location will not be mentioned in this study to protect the privacy of the data provider company. The acquisition in this study consisted of 30 research lines consisting of 26 main lines and 4 cross lines. The distances between the main and cross lines were 50 and 325 m, respectively. The total research line distance is 42,000 m or 42 km. The survey area was 1.4 km x 1.4 km, and the selection was based on the length of the anchor wire of the Jack-up rig itself, which was 700 m long (see Fig. 1). This research was conducted to determine the potential geohazard during the Jack-up rig entry process to the offshore platform by using

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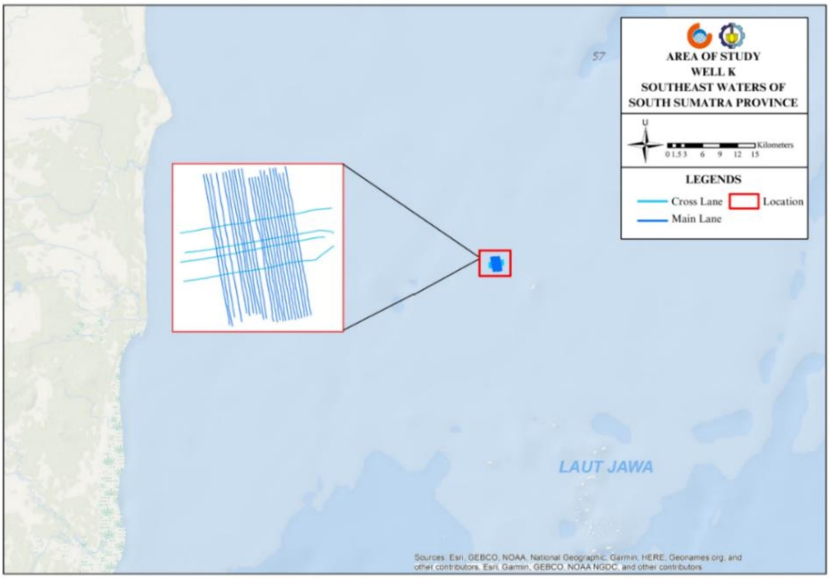
bathymetry data and seabed feature images. The other data used as supporting data to correct the interpretation included a map and a list of seabed features that could become a geohazard.
Fig. 1. Research location in Southeast waters of South Sumatera

The survey at the research site was conducted using instruments consisting of Single



Beam Echosounder, Multibeam Echosounder, and Side Scan Sonar. The selection of tools such as the Single Beam Echosounder in this study is based on their specific advantages and suitability for addressing the objectives of the geohazard survey. The SBES is widely recognized for its reliability and accuracy in providing depth measurements of the seabed, making it an essential tool for understanding the bathymetric profile. Unlike other alternatives, the SBES offers simplicity and cost-effectiveness while maintaining sufficient resolution for initial site assessments. Its capability to deliver precise data on seabed topography is crucial for identifying potential hazards, such as pockmarks or uneven surfaces, which may affect the stability and positioning of jack-up rigs. Coupled with complementary tools like the Multibeam Echosounder (MBES) and Side Scan Sonar (SSS), the SBES ensures a well-rounded approach to data collection, enhancing the overall robustness of the survey results. This rationale underscores the deliberate choice of the SBES in combination with other instruments to achieve a comprehensive and accurate geohazard analysis.

3 Results and Discussion

3.1 Topographic Conditions

The data obtained by the Multibeam Echosounder were in the form of the depth areas of the water area used for the study and then mathematically checked with depth data obtained from the Single Beam Echosounder in the form of depth points along the lane traveled during acquisition. This method was used for data quality checking of Multibeam Echosounder because the availability and undoubtedly data were measured using Single Beam Echosounder. However, the Multibeam Echosounder can survey full-coverage areas which is critical for oil and gas platform safety.

Furthermore, this research utilizes Side Scan Sonar (SSS) data to interpret underwater features related to underwater geohazards near the platform. Geometric correction in SSS is a correction that is generally carried out in the blind zone of the image results with low backscatter intensity, where the stages consist of bottom tracking and slant range corrections. However, geometric correction is mainly carried out to determine the actual position of the pixel. Meanwhile, radiometric correction is a correction that consists of several stages such as Beam Angle Correction (BAC), Automatic Gain Control (AGC), Empirical Gain Normalization (EGN), and Time-Varying Gain (TVG). The purpose of radiometric correction on SSS images is to correct matters related to the backscatter intensity of Side Scan Sonar (TVG) images [6]. The method of processing SSS data uses the post-processing method, namely processing Side Scan Sonar image data in the form of interpretation [7].

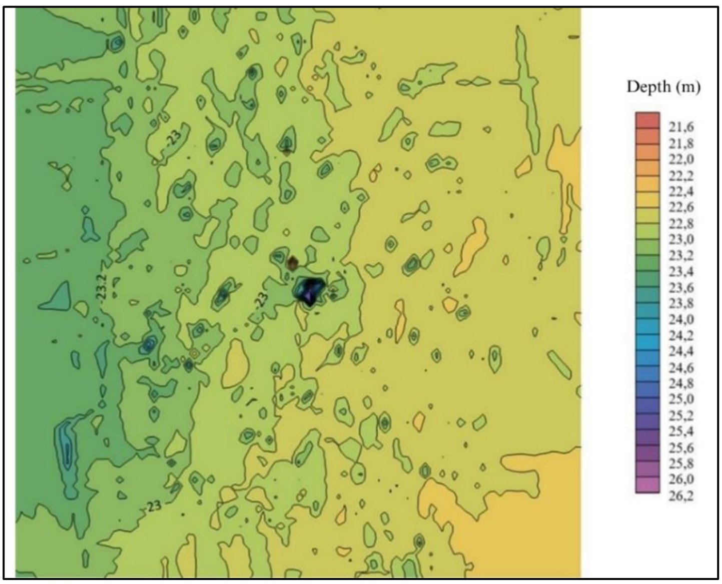


Fig. 2. Depth determination in the study area

Based on the depth legend of the map, the depth of the area shown in Figure 2 when viewed from east to west of the water depth area map indicates that the brightness of the color decreases (darkens). This indicates that the area has a deeper depth than other areas. Bathymetry survey results from Single Beam Echosounder and Multibeam Echosounder show that the depth of the study area was in the range of 22–23.9 m. The depth value shows that the study area has a sloping topographic shape because there are no anomalies or significant depth differences. After all, the difference in the depth of the survey area is only in the range of 1–2 m. This is validated by the depth points obtained from the Single Beam Echosounder, which on the map are represented by the depth number values, represented by the numerical value of the depth.

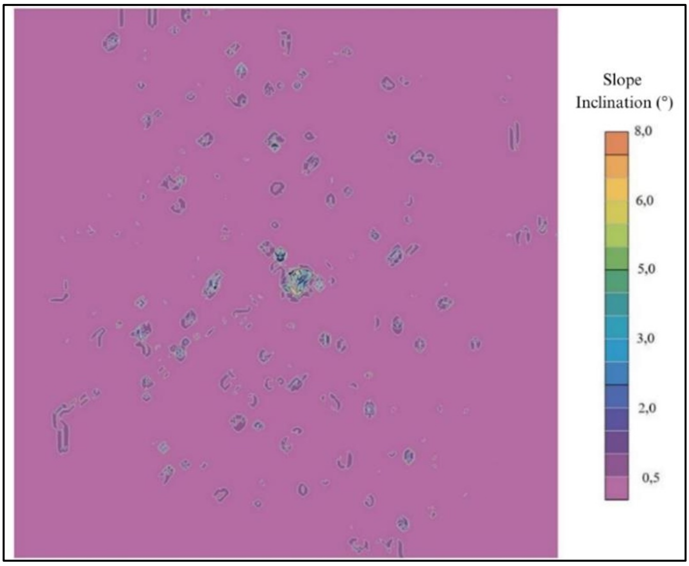


Fig. 3. Slope inclination in the study area

In Figure 3 the slope of the seabed in most of the study area ranges from 0°-2°, but in the middle of the waters of the study area, there is a significantly different value of the degree of slope, namely in the range of values from 5° to 7°. This can occur because at that location, there is a K platform, and during the depth survey, the closest location around the K platform is avoided due to constraints on the ship maneuvering process. Thus, affects the interpolation results of depth data in the area. With the seabed slope in the study area in the value range of 0° to 2° or in the almost flat classification category, the seabed in the study area is a safe area for jack-up rig operations.

3.2 Seabed Features

The seafloor appearance map has gone through a series of data processing stages consisting of playback, slant range correction, and mosaic creation.

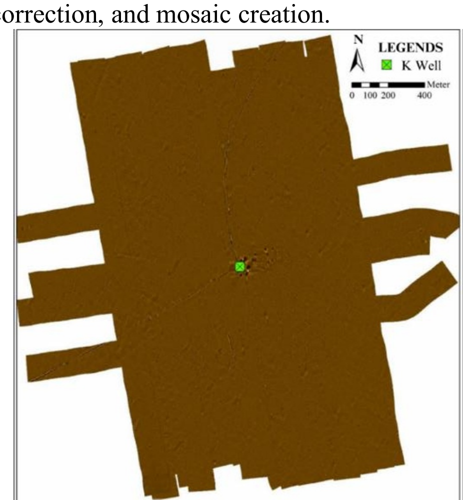


Fig. 4. Side Scan Sonar image mosaic in the study area

Thus, after being combined, it will form a Side Scan Sonar image mosaic as shown in Figure 4, the slant range correction that has been performed produces an image that has been corrected for slant range, so that the slant range corrected image will be clean from the blind zone or first return at nadir position and will represent the actual object position. After the slant range corrected image of the seafloor features, an image showing the seafloor features in the study area was produced more clearly. The appearance of the seabed that can be seen from the image capture of seabed features consists of a Jack-up Footprint, Spud Can Drag Scar, Seabed Scar, exposed pipe, and Subsea Cable.

3.2.1 Exposed Pipelines

In the study area, Side Scan Sonar and Multibeam Echosounder detected three subsea pipes of different sizes connecting platform K with other platforms. Table 1. is detailed information on the three subsea pipelines in the study area that had to be considered during the entry of the jack-up rig onto the K platform. The presence of subsea pipelines must be included in the calculations when planning and lowering the anchor as the rig approaches platform K. This needs to be done to minimize the occurrence of anchors or other objects being caught in subsea pipelines.

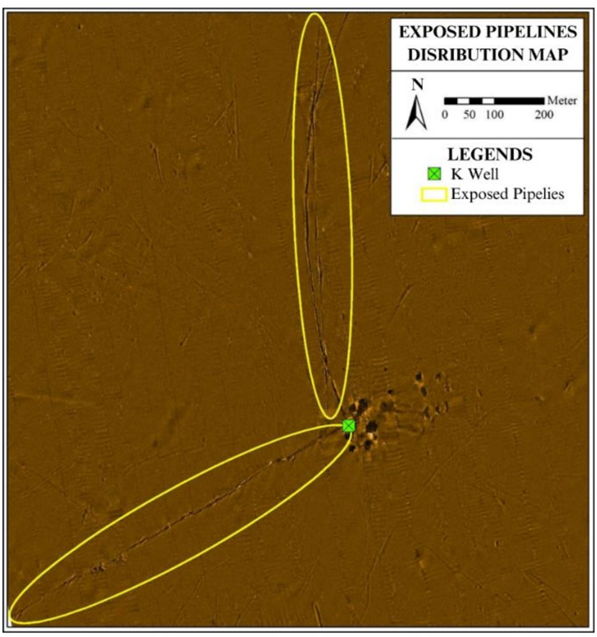
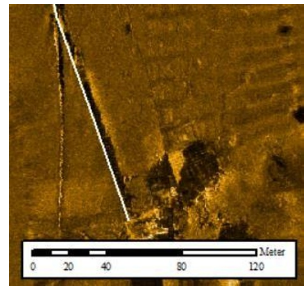
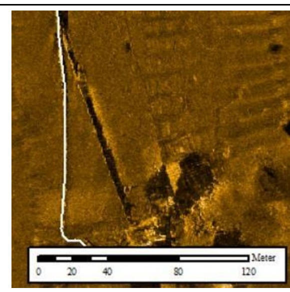
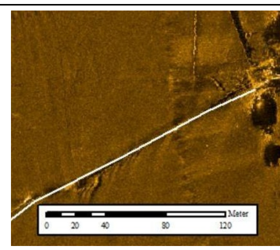


Fig. 5. Exposed pipeline features in the study area

Table 1. Details of exposed pipelines in the study area

Feature Name	Feature Types	Feature Image
Exposed Pipeline 1	16" pipeline from platform K leads to the Northeast	
Exposed Pipeline 2	16" pipeline from platform K leads to the Northeast	
Exposed Pipeline 3	16" pipeline from platform K heading Southwest	

3.2.2 Subsea Cable

The next feature is submarine cables. Subsea cables often carry critical communication data or electrical power. If an anchor from a rig or other object hits or snags on these cables, it can cause significant physical damage, such as a break in the cable or damage to the coating. At this study site, three subsea cables were observed around the waters of the study area with different cable sizes. The visualization is shown below.

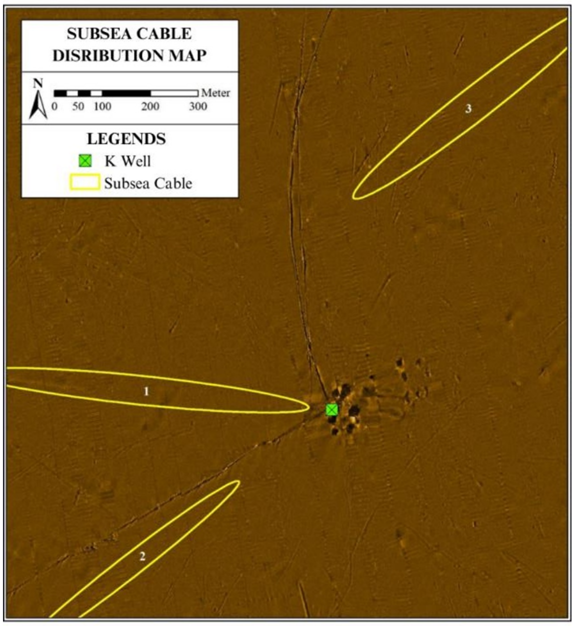
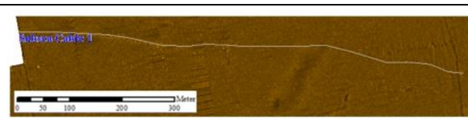
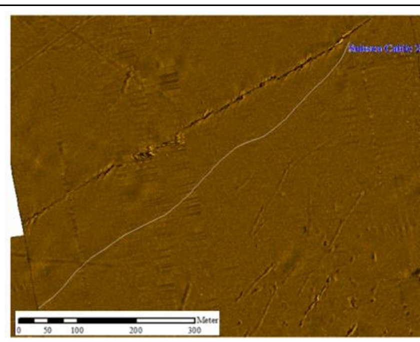


Fig. 6. Subsea cable in the study area

Locations where subsea cables are indicated must be included in the calculations to determine the path of rig entry with the jack-up rig. This is because subsea cables are commonly used to transmit communications data, including internet, telephone and other critical data transmissions. Damage to these cables can disrupt communication services and have far-reaching impacts on various sectors due to delays in information delivery, including businesses and emergency services. In addition, damaged submarine cables can increase operating costs and disrupt planned business-related schedules. As a result, it can cause great economic loss.

Table 2. Details of subsea cable in the study area

Feature Name	Feature Description	Feature Image
Subsea Cable 1	The cable route is partially visible and leads to the South-West from platform K	
Subsea Cable 2	The cable route is partially visible and leads to the South-West from platform K	

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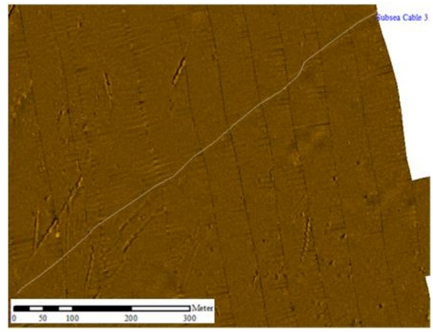
Exposed Pipeline 3	The cable route is partially visible and leads to the North-East from platform K	

3.2.3 Jack-up Footprint

Furthermore, 13 jack-up footprints were identified and can be observed in Figure 7. These footprints were caused by rig entry activities in the past. The following is a view of the jack-up footprints. The shape of the seabed feature recorded by the Side Scan Sonar and its depth recorded by the Multibeam Echosounder is obtained. The jack-up footprint located closer to Platform K shows a greater depth compared to the jack-up footprint located further away from platform K. This is due to the movement of the rig approaching the platform, where the height level of the rig's foot when it is in the intended location will be more penetrating compared to the position of the Jack-up rig when in the soft print so that the depth is more significant.

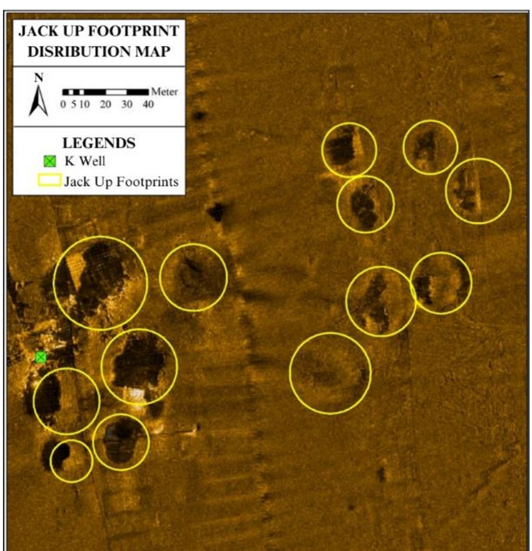
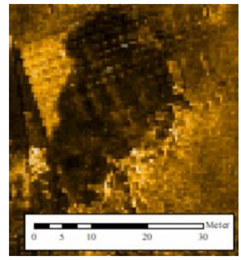
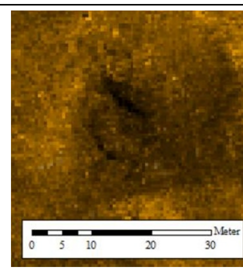
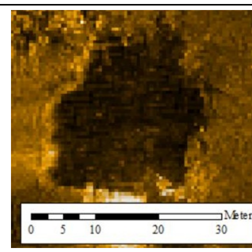
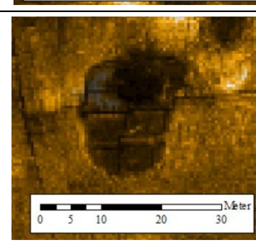
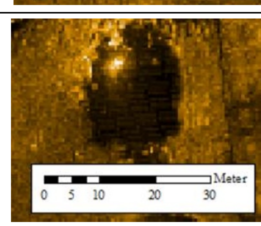
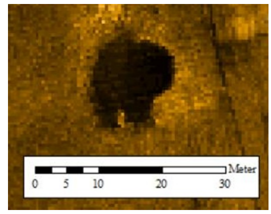
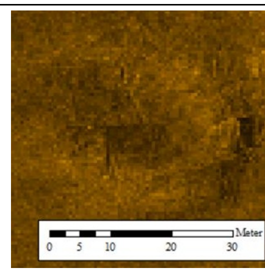
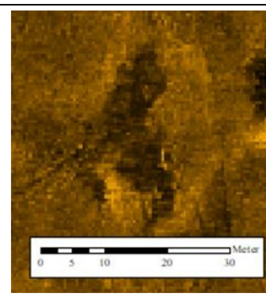
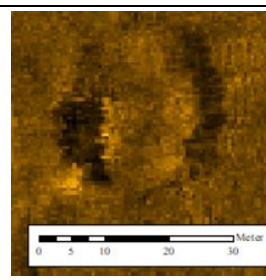
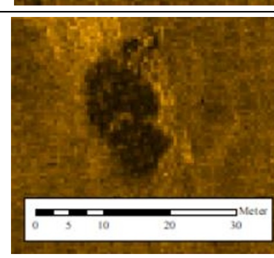


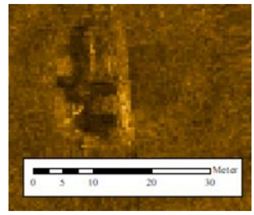
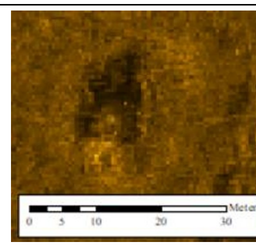
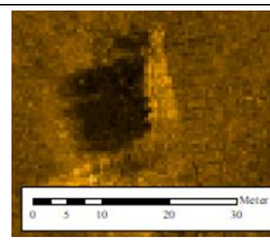
Fig. 7. Jack-up footprint in the study area

The presence of jack-up rig footprints needs to be calculated during the rig entry process, where jack-up rig footprints can increase the potential for slipping off the rig entering the platform. However, the presence of jack-up rig footprints in a section of the study area can also be a sign that the area is safe to travel through because in the past there have been jack-up rigs that performed rig entry through the platform. Previously, a jack-up rig was used to perform the rig entry process through the area. Below are the details of the jack-up footprint around platform K.

Table 3. Details of jack-up footprint in the study area

Feature Name	Dimension (L x W x D in m)	Distance from Platform K (m)	Feature Image
JUFP 1	27,817 x 16,748 x 3,300	15,908	
JUFP 2	41,001 x 23,569 x 5,200	37,634	
JUFP 3	26,243 x 22,905 x 1,400	21,073	
JUFP 4	11,244 x 10,312 x 2,600	39,448	
JUFP 5	20,871 x 16,891 x 2,100	9,729	

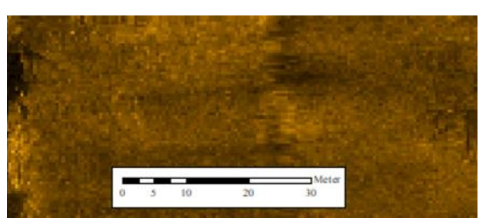
Feature Name	Dimension (L x W x D in m)	Distance from Platform K (m)	Feature Image
JUFP 6	13,534 x 7,236 x 1,800	42,923	
JUFP7	9,705 x 13,399 x 1,430	106,037	
JUFP8	22,370 x 24,598 x 1,010	146,034	
JUFP9	18,217 x 24,317 x 0,540	171,624	
JUFP10	20,097 x 24,100 x 0,800	148,492	

Feature Name	Dimension (L x W x D in m)	Distance from Platform K (m)	Feature Image
JUFP11	20,968 x 24,221 x 0,740	193,696	
JUFP12	23,451 x 29,580 x 0,920	181,064	
JUFP13	20,701 x 24,371 x 0,920	151,695	

3.2.4 Spud Can Drag Scars

In the study area, two spuds can drag scar seafloor features are observed. The Spud Can Drag Scars recorded by the Side Scan Sonar image are associated with the presence of jack-up footprints around the location of platform K. The presence of Spud Can Drag Scar indicates rig entry activity into the platform was previously conducted. The following are details of the spud can drag scar features in the study area.

Table 4. Details of spud can drag scars in the study area

Feature Name	Location	Length (m)	Feature Image
Spud Can Drag Scar 1	79,550 m North-East of Platform K	78,743 m	

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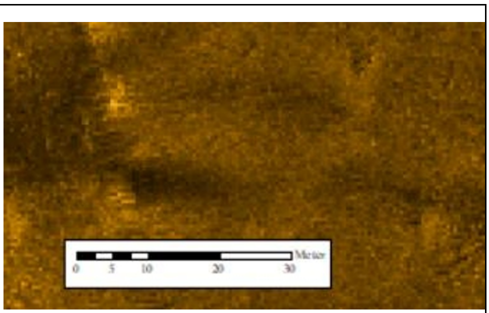
Spud Can Drag Scar 2	47,083 m South-East of Platform K	81,870 m	

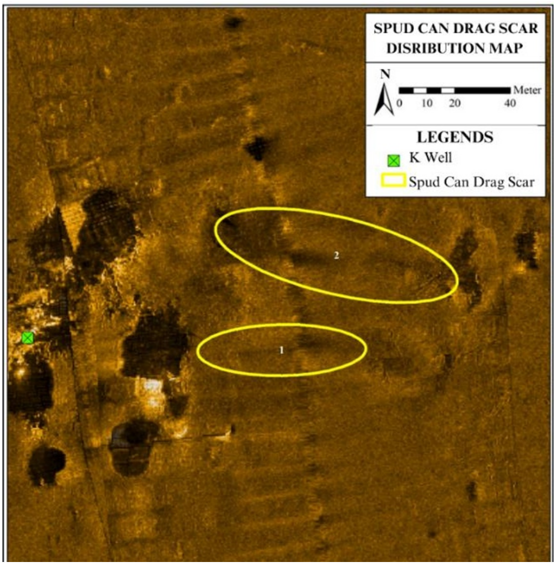


Fig. 8. Spud can drag scars in the study area

3.2.5 Seabed Scars

In addition to the presence of spud can drag scars in the study area, other seabed scars are also present in the study area. Various types of seabed scars with varying lengths and orientations were also observed in the study area. Seabed scars can be caused by fishing activities, resulting in anchor scars. In addition, other engineering activities such as seabed sand dredging and so on are also causes.

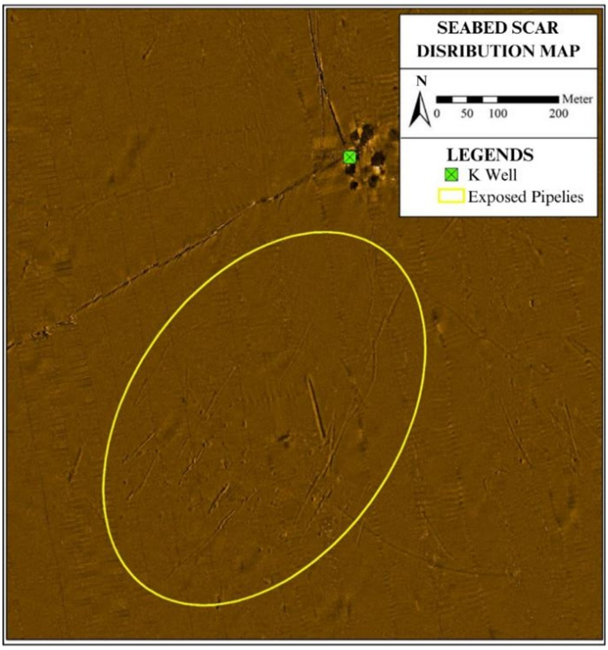


Fig. 9. Seabed scar in the study area

3.3 Sediment distribution

Sediment classification using Side Scan Sonar is performed by using the pixel value parameter of the segmented seabed surface mosaic image and validated using sediment distribution data on the seabed surface [8]. The following gives the sediment segmentation interpretation results using the pixel value parameters.

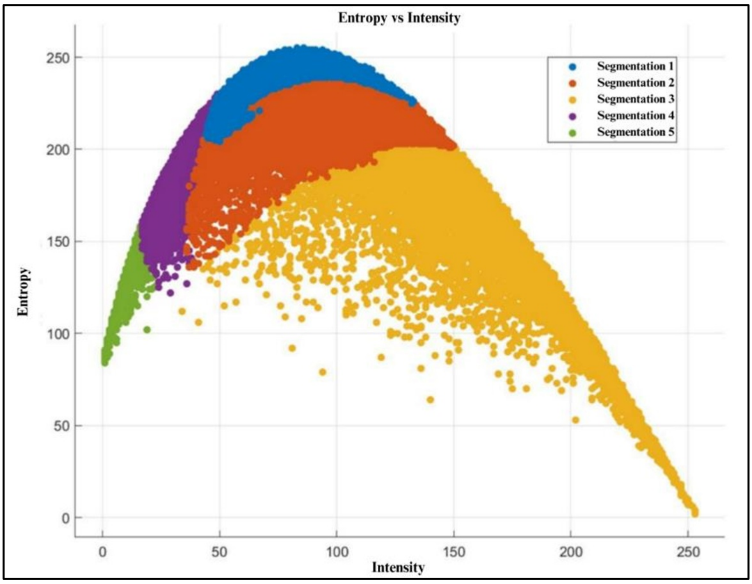


Fig. 10. Sediment-type segmentation result

From the segmentation results and supported by previous research data and geotechnical data in the study area, the results of the segmented data are divided into five segments. divided into five segments. Field data explains that the surface of the seabed in the study area consists of soft textured clay to very stiff textured clay. The combination of field data and the sediment segmentation results based on the pixel value parameter, the following types of seabed sediments were estimated for the study area.

Table 5. Sediment-type classification based on pixel value parameters

Segment	Sediment Class	Intensity	Entropy	Standard Deviation
1	Very Stiff Clay	44 - 133	204 - 255	30 - 81
2	Stiff Clay	36 - 150	136 - 244	69 - 176
3	Medium Stiff Clay	34 - 253	2 - 206	14 - 255
4	Soft Clay	17 - 49	122 - 230	13 - 137
5	Very Soft Clay	1 - 23	84 - 159	1 - 117

Based on research conducted by [9], it was found that sediment types in the range of very soft to very hard sediments consist of very soft clay, soft clay, medium stiff clay, stiff clay, and very stiff clay. The results of this research combined with the supported pixel value parameters, show that there are five types of sediment suspected, as in Table 4.10. The intensity value reflects the brightness of the pixel in the image. The entropy value reflects the texture of the seabed sediment. Low intensity and entropy values indicate that the seafloor sediments are detected as fine sediments, which are visually characterized by zones that have low brightness in the grayscale image. Whereas low entity and entropy values indicate that the seabed sediments have a coarse texture with bright zones in the gray-scale image [10].

In the image processing stage when extracting pixel value parameters, the intensity value is represented by the pixel value itself. In grayscale images, there is only one intensity value per pixel, which facilitates the analysis process in the context of image processing. Generally, pixel intensity values range from 0-255, especially in grayscale images. The range allows the representation of 256 different gray levels, with a value of 0 having the darkest color (black) and a pixel value of 255 having the lightest color (white). In this study, it was found that the intensity and entropy values of the 1st segmentation showed the highest values when compared to the other four classes, with intensity values of 44-133 and entropy values of 204-255. With these results, it is suspected that the first segmentation is a sediment with a type of clay that has a very hard texture. Meanwhile, the 5th segment has the lowest intensity and entropy values of the other four segments, with intensity values of 1-23 and entropy values of 84-159. This indicates that the 5th segment has sediments with a very soft textured clay type.

3.4 Rig Entry Route

In this study, rig entry route planning analysis of parameters consisting of seabed slope and seabed feature location was conducted using features in geospatial data processing software. The classification of seabed slope is based on the United Soil System Management (USSM), while the location of seabed features is based on seabed image data obtained from Side Scan Sonar acquisition. Based on the results of the bathymetry data processing, it was found that the research area has a gentle seabed topography for the rig entry process. In providing recommendations for rig entry routes, it must be ensured that the location is safe within the slope of the seabed and free from obstacles of seabed features that endanger the rig entry process.

Table 6. Sediment type classification based on pixel value parameter

Slope Inclination (°)	Slope Value	Features Existence	Feature Value	Total	Description
0° - 2°	0,333	Nothing	0,000	0,333	Safe
		Spud can drag scars	0,167	0,500	Unsafe
		Jack-up footprints	0,334	0,667	Unsafe
		Seabed scars	0,501	0,834	Unsafe
		Subsea cable	0,835	1,168	Dangerous
		Exposed pipelines	1,000	1,000	Dangerous
2° s.d. 4°	0,667	Nothing	0,000	0,667	Safe
		Spud can drag scars	0,167	0,500	Unsafe
		Jack-up footprints	0,334	1,001	Unsafe
		Seabed scars	0,501	1,168	Unsafe
		Subsea cable	0,835	0,835	Dangerous
		Exposed pipelines	1,000	1,667	Dangerous
4° s.d. 8°	1,000	Nothing	0,000	1,000	Unsafe
		Spud can drag scars	0,167	0,834	Dangerous
		Jack-up footprints	0,334	1,334	Dangerous
		Seabed scars	0,501	1,501	Dangerous
		Subsea cable	0,835	1,835	Dangerous
		Exposed pipelines	1,000	2,000	Dangerous

Seabed slope in the study area is divided into three categories based on its nature [11], a value of 0° to 2° which is included in the classification of almost flat or flat slopes, followed by 2° to 4° which is included in the classification of slightly sloping or sloping, then the last classification with a value of 4° to 8° which is included in the classification of high magnitude sloping or undulating nature. A slope of 0° to 2° has a weight value of 0.333 because the value of the seabed slope is not a threat that needs special attention in the rig entry process. For a slope of 2° to 4°, it has an influence but is not significant, so it gets a weight of 0.667. And for a slope of 4° to 8° it has the potential to become a threat in the rig entry process, so it gets the largest weight.

Fig. 11. Rig entry route recommendation map

Based on the results of the parameter processing that has been carried out, three classifications of locations are produced, consisting of hazardous areas, unsafe areas, and safe areas. Hazardous areas are categorized as areas that are dangerous due to the presence of seabed features and slopes of 4°-8°. Unsafe areas were categorized as hazardous due to the presence of seabed features and supported by a slope range of 2°-4°. Safe and recommended areas are due to the presence of seabed features and a slope of 0°-2°. By considering the slope of the seabed and seabed features that have the potential to become a geohazard, a route recommendation map was obtained for the rig entry. The rig entry process was not carried out in the North area of the well because in that area there are some very crucial seabed features, namely two exposed pipelines, one subsea cable, and seabed scars that are quite numerous and scattered.

4 Conclusion

The depth of the seabed in the K well study area is in the value range of 22 to 23.9 meters validated by Single Beam Echosounder and Multibeam Echosounder. The morphology of the seabed in the study area tends to be almost flat with a local seabed slope in the range of 0° to 2°. The main seabed features observed in the study area consist of exposed pipelines, Jack-up rig footprints, spud can drag scar and seabed scar. Segmentation results based on pixel value parameters show that the suspected sediment distribution based on segments covering the seabed is dominated by soft-textured clay sediments. Based on the weighting results, the jack-up rig is recommended to perform rig entry through the Northeast - East side of the platform, to avoid the three exposed pipes located in the Northeast and Southwest of platform K, the three subsea cables located in the Southwest, Northwest, and Northeast of platform K, and the cluster of seabed scars located in the South and North of platform K.

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