E-ISSN 2541-2116
ISSN 2443-2083

Jurnal Geomine, Volume 10, Nomor 2: Agustus 2022, Hal. 145 - 155

Determination of Relative Error in Coal Resource Classification Based On Geostatistical Drill Hole Spacing Analysis: A Case Study of Coal Deposits at Batang Hari, Jambi

Muhammad Fadhli, Budhi Setiawan*
Geological Engineering Study Program, Sriwijaya of University, Indonesia
**Email: budhi.setiawan@unsri.ac.id*

SARI

Umumnya penentuan klasifikasi sumber daya hanya bersifat kualitatif berdasarkan faktor geometri dan kompleksitas geologi yang mengontrol. Seiring ditemukannya wilayah prospek yang cenderung memiliki karakteristik endapan yang cukup heterogen, maka diperlukanlah metode yang dapat digunakan untuk meningkatkan tingkat kepercayaan dalam penentuan *Driil Hole Spacing Optimum*. Penelitian ini menggunakan penerapan geostatistik dengan metode *Global Estimation Variance* (GEV), berdasarkan nilai relatif error dari masing-masing parameter yang digunakan yaitu geometri ketebalan dan kualitas berupa Ash dan VM. Penelitian ini dilaksanakan di Desa Jangga Aur, Kecamatan Bathin XXIV, Kabupaten Batang Hari, Provinsi Jambi Wilayah Kerja PT Berkat Bara Persada *Jobsite* PT Inti Bara Nusalima. Hasil dari *Drill Hole Spacing Analysis* (DHSA) akan didapatkan *spacing optimum* pada klasifikasi sumber daya berdasarkan nilai relatif eror yaitu 0-10% untuk sumber daya terukur, 10-20% untuk sumber daya tertunjuk, dan > 20% untuk sumber daya tereka yang dilakukan pada seam utama. Berdasarkan hasil penelitian didapatkan bahwa seam utama yang digunakan adalah Seam D, selanjutnya jarak spasi titik bor pada lapisan batubara daerah penelitian yang memiliki jarak rata-rata 80 m, dengan analisis geostatistik dapat ditingkatkan hingga jarak 250 m pada sumber daya terukur, sumber daya tertunjuk 450 m dan tereka 800 m.

Kata kunci: Geostatistik; GEV; DHSA; Relatif Error

How to Cite: Fahdli, M., Setiawan, B., 2022. Determination of Relative Error in Coal Resource Classification Based On Geostatistical Drill Hole Spacing Analysis: A Case Study of Coal Deposits at Batang Hari, Jambi. Jurnal Geomine, 10 (2): 145-155.

Published By:
Fakultas Teknologi Industri
Universitas Muslim Indonesia
Address:
Jl. Urip Sumoharjo Km. 05
Makassar, Sulawesi Selatan
Email:
geomine@umi.ac.id

Article History:
Submit 18 Juli 2022
Received in from 18 Juli 2022
Accepted 02 Agustus 2022

E-ISSN 2541-2116
ISSN 2443-2083

ABSTRACT

Generally, the determination of resource classification is only qualitative based on the geometric factors and geological complexity that control it. However, as the prospect area is found to have a reasonably heterogeneous sediment characteristic, a method is needed that can be used to increase the level of confidence in determining the Optimum Drill Hole Spacing. Therefore, this study uses the application of geostatistics with the Global Estimation Variance (GEV) method based on the relative error value of each parameter, namely the thickness geometry and quality in the form of Ash and VM. This research was carried out in Jangga Aur village, Bathin XXIV District, Batang Hari Regency, Jambi Province, Working Area of PT Berkat Bara Persada Jobsite PT Inti Bara Nusalima.The Drill Hole Spacing Analysis (DHSA) results will obtain optimum spacing on resource classification based on relative error values, namely 0 to 10% for measured resources, 10 to 20% for indicated resources, and > 20% for Inferred resources carried out the on-seam reference. Based on the results of the study, it was found that the seam reference used was Seam D, then the spacing distance of the drill hole on the coal seam of the research area, which had an average distance of 80 m, with geostatic analysis could be increased up to a distance of 250 m in measured resources, indicated resources of 450 m and inferred 800 m.

Keywords: *Geostatistics; GEV; DHSA; Relative Error*

INTRODUCTION

The research area has quite diverse characteristics of the geological conditions that control, and using the qualitative classification of resources tends to be unmeasurable and challenging in its implementation In the calculation of resources, it is strongly influenced by the type of coal deposit, the class of geological complexity that controls, the density of information points, and the feasibility of the location, as well as variations in coal quality consisting of aspects of ash, density and volatile matter (Srivastava, 2013; Iskandar Zulkarnain and Waterman Sulistyana Bargawa, 2018). Therefore, drilling activities and descriptions of lithology results are very influential components (Jeuken, et al., 2017).

Carry out spatial interpolation in determining coal distribution patterns can be done with many methods, including deterministic methods (FEM and IDW), geostatic methods (kriging and cokriging), spatial statistical methods (generalized least squares), machine learning methods (random forest and support vector machines) and hybrid methods (random forest regressing kriging) (Li & Heap, 2014).

Based on these problems, using geostatistics methods is the answer to explanations related to understanding quantified geological conditions, especially in determining the drill hole spacing. (Bertoli *et al.*, 2013) introduced specific geostatistics for the resource classification calculation technique, namely Drill Hole Spacing Analysis (DHSA) using Global Estimation Variance (GEV) with the parameters of the thickness geometry and quality variance in a coal seam.

Jurnal Geomine

E-ISSN 2541-2116
ISSN 2443-2083

Previous studies on geostatistics have also been discussed by(Cornah, Vann and Driver, 2013) which discuss comparing three geostatistics methods (global estimation variance, discrete Gaussian model, and conditional simulation) in determining the drill hole spacing. (Heriawan *et al.*, 2020) also discussed the distance of drill hole spacing in seam thickness data and total sulfur that is not stationary.

Therefore, this study can be used to determine the relative error value in determining the distance of the optimum information point density so that it can be an evaluation and additional information on use (SNI:5015, 2019; KCMI, 2017) which still uses descriptive analysis of the parameters of geological complexity, geometry and quality of coal in determining resource classification.

DATA AND METHODOLOGY

Datasets

Data collection activities are carried out through exploration drilling activities and geometric measurements. Exploration drilling is carried out to determine the stratigraphic sequence of layers, lithological characteristics, and verification of thickness, depth, and geometric character in coal which is carried out using the open hole, full coring, and touch coring methods and the interim retrieval technique based on (JORC, 2012) while geometry measurements are carried out to measure the alignment, shape of layers and the characteristics of the constituent lithology in the mine openings around the area to be carried out coal exploration.

Furthermore, data analysis was carried out in the form of making databases in the form of lithology, surveys, and quality based on the results of laboratory analysis and geological models so that drilling data amounted to 30 data consisting of 4 seams (Figure 1). In the process of data processing to determine the optimum information point density, and it is carried out using the parameters of thickness, ash, and volatile matter.

Basic Geostatistics

The initial process carried out is a descriptive statistic test which is carried out to determine the frequency, histogram, and data probability. Then, based on the descriptive statistic test, the data's probability, variability, and normality will be known so that the univariate structure of the data distribution is known.

E-ISSN 2541-2116
ISSN 2443-2083

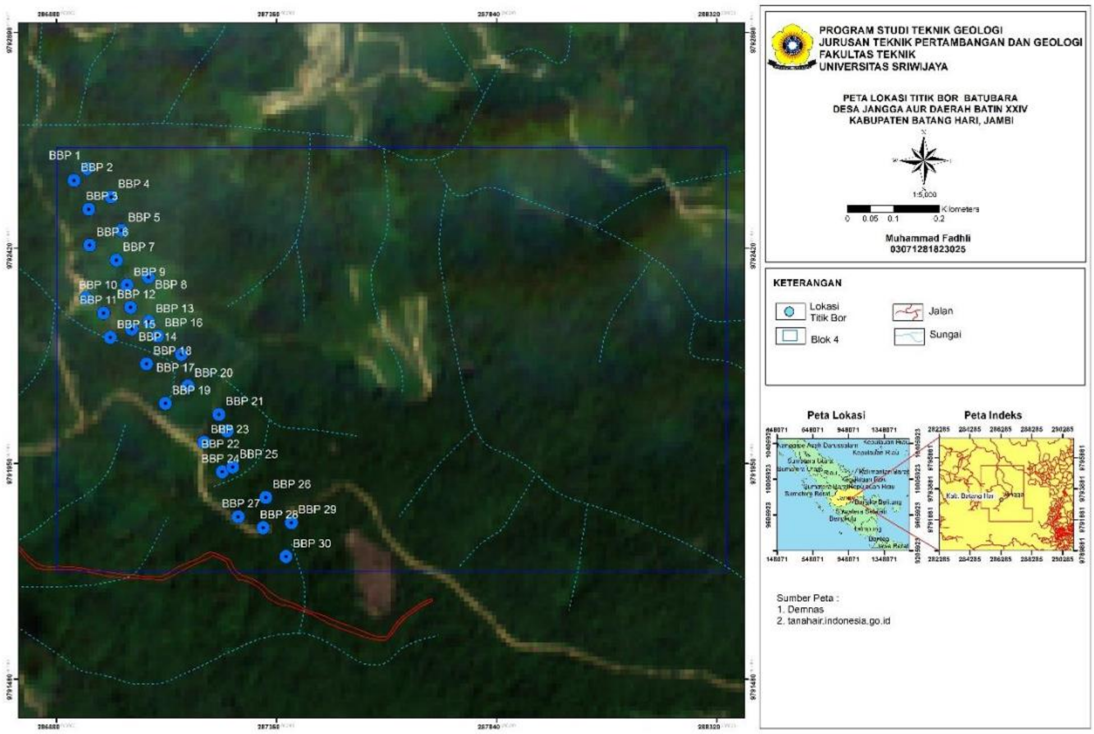

Figure 1. Drill Hole Location Map

After a descriptive static test is carried out, a spatial statistical test uses a variogram. It begins with exploration, modeling, and analyzing stationarity assumptions in the data. Furthermore, an experimental variogram based on try and error was carried out to obtain a calculation of pair tolerance and distance between unturned data to get a certain lag depending on the number of N data with the equation (David, 1977):

$$\gamma(h) = \frac{\sum_{i=1}^{n} \; [z(xi) - z(xi+h]^2}{2\,N\,(h)} \quad (1)$$

After that, the model variogram fittings are carried out so that the unique components of the variogram are known, namely the sill values (C), nuggets (C0), and Range (a).

Global Estimation Variance (GEV)

It is a method used to find the relative error value globally, which is described through a spherical model with nugget variance values = 0 and Sill = 1 (Figure 2.). However, if the nugget and sill values are not qualified, it is necessary to know the estimated variance values by equation (Cornah, Vann and Driver, 2013):

$$\sigma_E^2(r) = C0 + (C0^{*}\sigma^2) \quad (2)$$

The estimated variance value is obtained from the division of the estimated variance value and the number of blocks (*N*), namely:

$$\sigma_E^2(R) = \sigma_E^2(r)/N \quad (3)$$

E-ISSN 2541-2116
ISSN 2443-2083

To find out the relative error value in the estimated variance is obtained through the equation:

$Relative\ Error = \pm\sigma_E\ .100\%/\ mean$ (4)

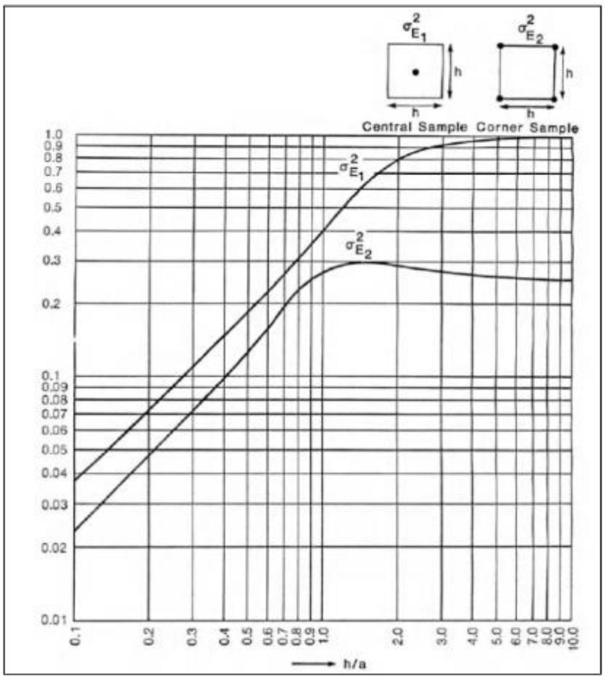

Figure 2. Nomogram of Variation/Estimation Extension Values In Spherical models (Annels, 1991).

Global estimation variance values are obtained based on a nomogram, then used to estimate the relative error value. Then, data plotting is carried out between the relative error values compared to the distance of drill hole spacing. For example, the classification of resources based on relative errors of 10% measured resources, 20% indicated resources and 50% as inferred resources (Table 1).

Table 1. Classification of Resources By Relative Error Value (Souza, et al., 2010; JORC, 2012)

Resource classification	Max. Extrap olation	Max. Spacing	Error Tolarance
Measured	500	+1 Km< 500 m	0-10%
Indicated	1000	+2Km<1 Km	10%-20%
Infernal	2000	+4 Km	>20%

RESULTS

Coal Geometry

In the research area, there are four coal seams (Figure 3): Seam B with a layer thickness of 2.10 to 3.09 meters, gloss bright with dull, moderately strong compactness, uneven

E-ISSN 2541-2116
ISSN 2443-2083

fragments, claystone inter burdens, and clay silt partings. Seam C was thin (0.67 to 1.8 meters), with uneven fragments, moderately strong compactness, and sandstone and clay silt inter burden. Seam D is the central target seam with a thickness of 1.70 to 5.04 meters, bright with dull gloss, moderately strong compactness, uneven fragments, and partings in the form of resin. Finally, seam E, with a layer thickness of 1.30 to 2.70 meters, has an inter burden in the form of clay silt, a bright gloss with dull, uneven shards, and moderately strong compactness.

The process of coal formation in the research area in the Jambi Sub-Basin, Cendurung South Sumatra Basin, has thin coal (Nurdrajat, et al., 2018). In addition, a tectonic activity controls the formation of geological structures in the form of faults controlled by the Paleogene half-graben pattern (Ginger & Fielding, 2005), resulting in the study area having a relatively steep dipping of 34 to 40.

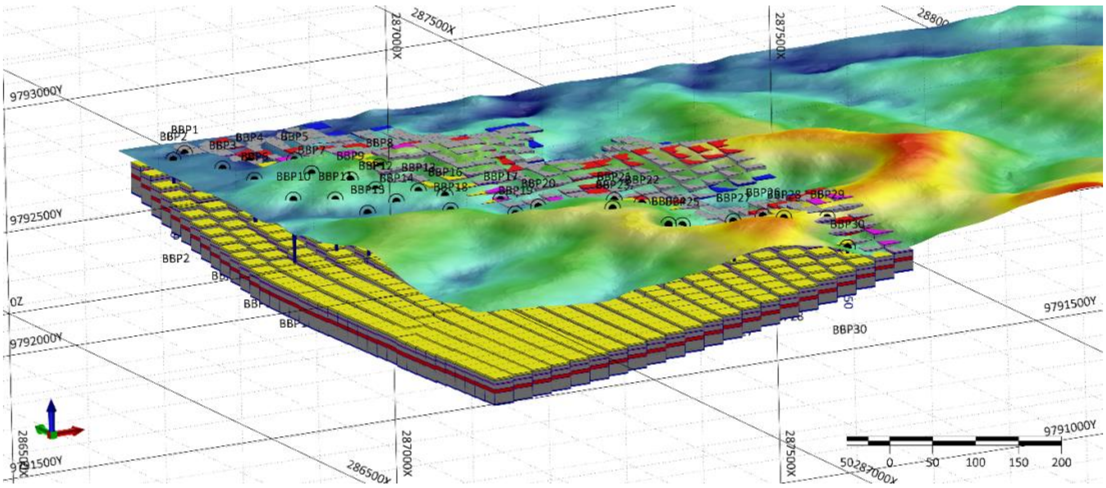

Figure 3. Coal Geometry Conditions In The Study Area

Geostatistical Borehole Spacing Analysis

Determining the drill hole spacing analysis begins with a descriptive static test using coal thickness and quality parameters (Ash and VM). This analysis was carried out to determine the data's probability, variance, and structural level reflecting anisotropy/isotropy. Based on fundamental statistical analysis, the results were obtained that Seam D is a seam reference that will be used in determining relative error in determining the distance of the optimum information drill hole. His justification is based on the degree of variability and availability of the amount of data seam D is the best among other seams (Table 2).

Furthermore, after implementing the descriptive statistical test, a spatial static test was carried out using variogram modeling. Variogram fittings are performed on thickness, ash, and VM parameters. Variogram fittings were performed to match experiential and theoretical models, which in this study used spherical models (Figure 4).

Jurnal Geomine
E-ISSN 2541-2116
ISSN 2443-2083

Table 2. Descriptive Statistical Test Parameters

Parameter	Min	Max	Count	Sum	Mean	Median	Variance	Std. Dev	Co.Variance
Thickness	1.7	5.01	29	119.99	4.13	4.06	0.42	0.65	0.157
Ash	2.36	3.06	29	97.62	3.36	3.33	0.1	0.32	0.09
VM	30.29	32.98	29	927.23	31.97	32.15	0.41	0.64	0.02

Process Variogram Fittings with Try and Error at an angular tolerance of 90^0 (Omnidirectional). The maximum distance (± 900 m) with a spacing lag value of 50 to 100 m and a lag tolerance of 15 m is based on the average distance of exploration drilling data. From the results of the variogram fitting, the sill (C), nugget (C0), and range (a) values will be obtained, which will later be used as the optimum information point distance with the global estimation variance method (Table 3). In the data from the relevant variogram results, the highest nugget value was obtained in the volatile matter (VM) parameter, which was 0.41, and the lowest in ash, which was 0.01. Nugget effect explains that quite erratic variations are formed in the distribution and distance between the data.

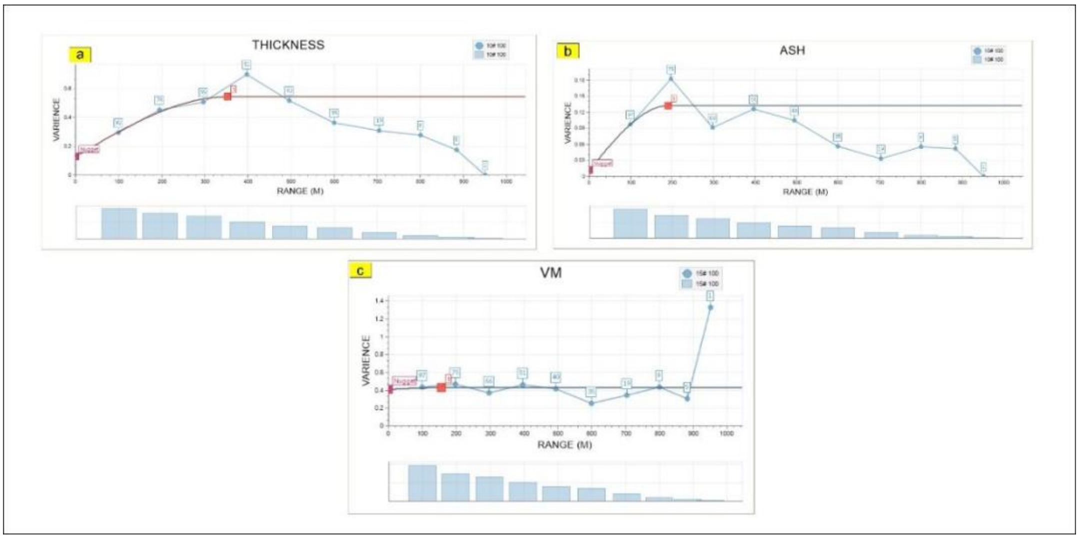

Figure 4. Semi-Variogram On a) Thickness Parameters; b) VM parameters; and c) VM parameters

Table 3. Spatial Statistical Test Parameters (Semi-Variogram) Using Spherical Models

Parameter	Nugget (C0)	Sill (C)	Range (a)	CoV
Thickness	0.129338809	0.544747	353.386	0.157
Ash	0.011475395	0.120774	190.553	0.09
Volatile Matter	0.410291717	0.429519	157	0.02

Table 4 shows the results of determining the relative error value using the global estimation variance (GEV) method. The variance value used in GEV calculations is obtained

E-ISSN 2541-2116
ISSN 2443-2083

from plotting against the nomogram model, which is then used to estimate relative error values.

Resource classification was then carried out based on plotting on the drill hole spacing analysis (DHSA) graph (Figure 5), which was carried out using the values of sill values (C), nuggets (C0), and range (a), resulting from the variogram fitting. The optimum relative error values used are 10% on measured resources, 20% on indicated resources, and 50% on 50% inferred resources. For example, in the Thickness parameter, the results obtained in the measured resource classification obtained a distance of 250 m with a relative error value of 10%, indicated resources at a distance of 450 m with a relative error value of 20%, and Inferred at a distance of 850 m with a relative error value of 50%. Finally, in the Volatile Matter (VM) parameter, the classification of resources is known. Obtained at a distance of 1,100 m with a relative error value of 10%, Indicated at a distance of 2,200 m with a relative error value of 20%, and Inferred at a distance of 5,500 m with a relative error value of 50%.

Table 4. An example of calculating the relative error value using the global estimation variance (GEV) method in the thickness parameter.

h	l	X	Y	_X	_Y	N	a	Co	C	h/a	l/a	Mean	Varians	σ^2Er	σ^2ER	σER	Error
100	100	462	846	4.62	8.46	39.09	353.4	0.129	0.545	0.283	0.283	4.13	0.10	0.181	0.005	0.068	3.23%
150	150	462	846	3.08	5.64	17.37	353.4	0.129	0.545	0.4245	0.4245	4.13	0.15	0.211	0.012	0.110	5.23%
175	175	462	846	2.64	4.83	12.76	353.4	0.129	0.545	0.4952	0.4952	4.13	0.17	0.222	0.017	0.132	6.26%
200	200	462	846	2.31	4.23	9.771	353.4	0.129	0.545	0.566	0.566	4.13	0.20	0.238	0.024	0.156	7.41%
250	250	462	846	1.85	3.38	6.254	353.4	0.129	0.545	0.7074	0.7074	4.13	0.25	0.266	0.042	0.206	9.78%
300	300	462	846	1.54	2.82	4.343	353.4	0.129	0.545	0.8489	0.8489	4.13	0.31	0.298	0.069	0.262	12.44%
350	350	462	846	1.32	2.42	3.191	353.4	0.129	0.545	0.9904	0.9904	4.13	0.35	0.320	0.100	0.317	15.03%
400	400	462	846	1.16	2.12	2.443	353.4	0.129	0.545	1.1319	1.1319	4.13	0.40	0.347	0.142	0.377	17.89%
450	450	462	846	1.03	1.88	1.93	353.4	0.129	0.545	1.2734	1.2734	4.13	0.43	0.364	0.188	0.434	20.60%
500	500	462	846	0.92	1.69	1.563	353.4	0.129	0.545	1.4149	1.4149	4.13	0.51	0.407	0.260	0.510	24.22%
600	600	462	846	0.77	1.41	1.086	353.4	0.129	0.545	1.6979	1.6979	4.13	0.60	0.456	0.420	0.648	30.76%
700	700	462	846	0.66	1.21	0.798	353.4	0.129	0.545	1.9808	1.9808	4.13	0.68	0.500	0.627	0.792	37.56%
800	800	462	846	0.58	1.06	0.611	353.4	0.129	0.545	2.2638	2.2638	4.13	0.83	0.581	0.952	0.976	46.31%
850	850	462	846	0.54	1	0.541	353.4	0.129	0.545	2.4053	2.4053	4.13	0.87	0.603	1.115	1.056	50.12%

From the results of plotting the DHSA graph, it can be seen that the spacing of the drill point on the coal seam of the study area, which has an average distance of 80m, with geostatistic analysis can be increased up to a distance of 250 based on the relative error value in the measured resource. Furthermore, when compared to the distance of information points according to (SNI: 5015, 2019), it can be seen that the study area is included in moderate geological conditions, but the distance of indicated and inferred resources has smaller values namely 450 m and 800 m.

E-ISSN 2541-2116
ISSN 2443-2083

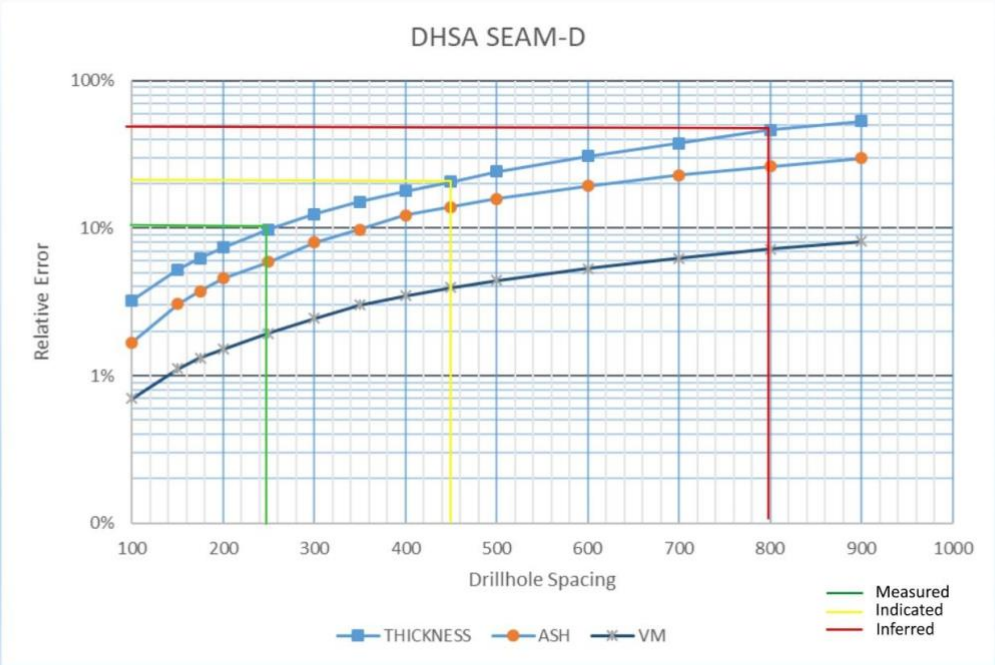

Figure 5. Graphic Drill Hole Spacing Analysis (DHSA) Seam D

CONCLUSION

The research area found four coal seams with a variety of variations both in thickness geometry and coal quality (VM and ash). The use of geostatistical methods with the determination of the relative error value is used to increase the level of confidence in the decision of the optimum borehole distance. The optimum drill hole spacing in the study area is seam D with a space of 250 m, 450 m, and 800 m.

When compared to (SNI:5015, 2019) for measured resources to have the same distance but for indicated and inferred resources to have smaller values, it can be known that the presence of variations, probabilities, normality in the thickness parameters and quality of coal significantly affects the determination of optimum drill hole spacing.

ACKNOWLEDGMENT

Gratitude for the grace of Allah SWT so that the author can complete the research. Thank you to Mr. Andreas Septiadi, Yonash Philetas I, and the Exploration Division as mentors, as well as all leaders and staff of PT Berkat Bara Persada who have allowed and assisted in the process of data collection and research implementation.

REFERENCE

Annels, A. E., 1991. *Mineral Deposit Evaluation: A Practical Approach.*. Netherlands, Springer.

Bertoli, O. *et al.* (2013) 'Geostatistical drill hole spacing analysis for coal resource classification

Jurnal Geomine
E-ISSN 2541-2116
ISSN 2443-2083

in the Bowen Basin, Queensland', *International Journal of Coal Geology*, 112, pp. 107–113. doi: 10.1016/j.coal.2012.12.010.

Cornah, A., Vann, J. and Driver, I. (2013) 'Comparison of three geostatistical approaches to quantify the impact of drill spacing on resource confidence for a coal seam (with a case example from Moranbah North, Queensland, Australia)', *International Journal of Coal Geology*, 112, pp. 114–124. doi: 10.1016/j.coal.2012.11.006.

David, M., 1977. *Geostatistical Ore Reserve Estimation.* New York, 2nd edition, Elsevier, p. 216.

Ginger, D. & Fielding, K., 2005. *The Petreleoum System and Future Potensial Of The South Sumatra Basin.* Jakarta, Proceedings Indonesian Petroleum Association Thirtieth Annual Convention & Exhibition, pp. 67-89.

Heriawan, M. N. *et al.* (2020) 'Drill hole spacing optimization of non-stationary data for seam thickness and total sulfur: A case study of coal deposits at Balikpapan Formation, Kutai Basin, East Kalimantan', *International Journal of Coal Geology*, 223(March), p. 103466. doi: 10.1016/j.coal.2020.103466.

Iskandar Zulkarnain and Waterman Sulistyana Bargawa (2018) 'Classification of Coal Resources Using Drill Hole Spacing Analysis (DHSA)', *Journal of Geological Resource and Engineering*, 6(4), pp. 151–159. doi: 10.17265/2328-2193/2018.04.003.

Jeuken, R., Xu, C. & Dowd, P., 2017. *Improving coal quality estimations using geostatistics and auxiliary.* Melbourne, The Australasian Institute of Mining and Metallurgy, pp. 5-13.

JORC, 2012. *The Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves.* Australia : The Joint Ore Reserves Committee of The Australasian Institute.

KCMI, 2017. *Kode Pelaporan Hasil Eksplorasi, Sumberdaya Mineral dan Cadangan Mineral Indonesia.* Jakarta: KCMI, IAGI, PERHAPI.

Li, J. & Heap, A. D., 2014. Spatial interpolation methods applied in the environmental sciences: A review. *Environmental Modelling & Software,* pp. 53: 173-189.

Nurdrajat, S, E., S, N. & A, E., 2018. Karakteristik Batubara Regresi dan Transgresi Formasi Muara Enim. *Bulletin of Scientific Contribution,* pp. 221-228.

SNI:5015, 2019. *Pedoman Pelaporan Hasil Eksplorasi, Sumber Daya, dan Cadangan Batubara.* Jakarta: Badan Standarisasi Nasional.

Souza, L. E., Costa, J. L. & Kopper, J. L., 2010. Comparative Analysis of the Resource Classification. *Applied Earth Science (Trans. Inst. Min. Metall. B) ,* Volume 119, pp. 166-75.

Srivastava, R. M. (2013) 'Geostatistics: A toolkit for data analysis, spatial prediction and risk management in the coal industry', *International Journal of Coal Geology*, 112, pp. 2–13. doi: 10.1016/j.coal.2013.01.011.