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ESTIMATION OF TIN RESOURCES USING INVERS DISTANCE WEIGHTED (IDW) AND NEAREST NEIGHBOR POINT (NNP) METHODS IN BANGKA TENGAH DISTRICT, BANGKA BELITUNG ISLANDS PROVINCE

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ABSTRACT
Indonesia is a country rich in tin minerals. Indonesia has 17% of the world's total tin reserves but produces 26% in 2020. This shows an unequal value between income and expenditure. Therefore it is necessary to calculate tin resources on a regular basis so that their availability is maintained. Here, two methods of calculating the estimated tin resources are used, namely the inverse distance weighted (IDW) and nearest neighbor point (NNP) methods. The estimation results using both methods are tin resources using the IDW method of 1,501,300 tons while using the NNP method 1,270,222 tons. In conclusion, there is a difference in the estimation results using the two methods of 231,078 tons or 18%. This difference is caused by the working of the two methods, namely the principle IDW method considers several closest points, while the NNP method considers the closest point.
INDEX TERMS ***Bangka Island, Estimation, IDW, NNP, TIN.***

I. INTRODUCTION
Indonesia is a country rich in natural resources. One of Indonesia's natural resources is mining. Minerals or mining materials are classified into minerals and coal. Minerals are solid objects that occur naturally of inorganic materials with a certain chemical composition. Indonesia's mineral reserves and resources are among the largest in the world. The following are Indonesia's Mineral and Metal Reserves and Resources [1] :

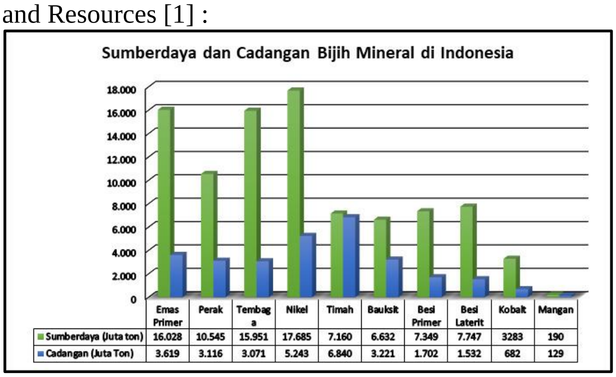

Figure 1. Mineral Ore Resources and Reserves in Indonesia (Source: Geological Agency, 2022)

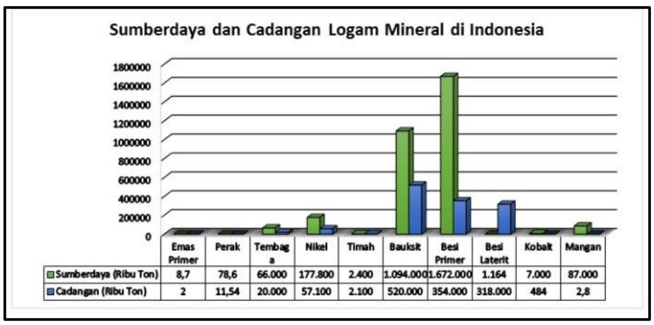

Figure 2. Metal Mineral Resources and Reserves in Indonesia (Source : Geological Agency, 2022)

mineral reserves places Indonesia on the list of countries with the highest mineral resources and production in the world. [1] Indonesia in the amount of production and mineral reserves as shown in the table below:

TABEL 1
INDONESIA'S POSITION IN THE WORLD IN TOTAL MINERAL RESERVES AND PRODUCTION

Minerals	World Reserve	World Production
Nickel	Number 1 in the world	Number 1 in the world

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	(24% of the world's Nickel Reserves)	(29% of Nickel reserves in the world)
Bauxite	Number 6 in the world (4% of the world's Bauxite Reserves)	Number 6 in the world (4% of the world's Bauxite reserves)
Copper	Number 7 in the world (3% of the world's Copper reserves)	Number 12 in the world (2% of the world's Copper reserves)
Gold	Number 5 in the world (5% of Gold reserves in the world)	Number 6 in the world (6% of Gold reserves in the world)
Lead	Number 2 in the world (17% of the world's Tin reserves)	Number 2 in the world (26% of the world's Tin reserves)

The table above shows that Indonesia plays an important role in the supply and production of world mineral resources. One that stands out is tin. Indonesia's tin deposits and reserves are scattered throughout the Bangka Belitung archipelago province. According to the Geological Survey, Indonesia's tin ore reserves reach 7,160 million tons with a total reserve of 6,840 million tons in 2022, while Indonesia's tin metal reserves reach 2,400,000 tons with a total reserve of 2,100,000 tons. [1] Indonesia's tin reserves are the second largest in the world in 2020 (17% of global reserves), but on the other hand, Indonesia will become the second largest tin producer in the world. same year. produces 26% of the world's reserves. The fact that we control 17 percent of the world's tin reserves but produce 26 percent of the world's tin production in 2020 is a result of an imbalance between income and expenditure. To maintain the availability of Indonesia's tin reserves, the government issued Law No. 3 of 2020. [2] In Article 36A of the Mineral and Coal Mining Law No. 4 of 2009, which reads "In the context of mineral and coal conservation, the owner of an IUP or IUPK in the production stage is required to carry out additional exploration activities every year and provide a budget". This law requires holders of Production Operation Permits to carry out additional research for new natural resources and prepare funds to maintain the stability of the supply of mineral resources in Indonesia.

The results of mineral exploration are the value of mineral resources and reserves. To find out the availability of domestic minerals, a calculation of mineral resources must be carried out so that production can be limited and not carried out on a large scale. Therefore, this article discusses a comparative calculation of tin resources using the inverse distance weighting (IDW) and Near Neighbor Point (NNP) methods for tin case studies in Central Bangka Regency, Bangka Belitung Islands Province.

II. STUDY LITERATURE AREA AND DATASETS

The following is an explanation of the research area that the author has done.

2.1. STUDY LITERATURE

2.1.1. Tin

Tin is a silvery-white metal with low roughness and *strength* , and has high thermal and electrical conductivity properties, has a brownish color with 4 associated minerals, namely monazite, zircon, ilmenite and quartz [3]. [4] Based on the method of formation, tin deposits can be grouped into two groups, primary tin deposits and secondary tin deposits.

2.1.1.1. Primary Tin

Primary tin deposits are tin formed directly from magma freezing. According to Andrian (2020) primary tin is tin deposits that have not experienced weathering and are generally in the form of polymetallic veins. The process of primary tin formation in the Bangka Belitung Islands began with the collision of the Sibumasu plate and the Indochina plate which then produced acidic magma (a silica content greater than 65%). The magma then breaks through the rock and freezes into granite. During this breakthrough process, the magma activity changed the composition of the surrounding rock a lot so that mineral deposits rich in tin were formed. Primary tin deposits are formed during the final moments of rock formation (temperature 800 – 400 degrees Celsius). At this temperature, many gases become residual solutions, including the SnF_4 compound . This compound reacts with water (H_2O) to form the compound SnO_2 (cassiterite). The mineral cassiterite is the main mineral for primary tin deposits.

2.1.1.2. Secondary Lead

Secondary tin deposits are tin that has been separated from the parent rock. The process of forming secondary tin deposits begins with the parent rock (granite rock) undergoing a tectonic process in the form of uplifting, cracking and fracture which then causes the rock to crack. Cracked granite sticking out to the surface of the earth meets the hot and humid nature of the tropical Indonesia which causes the granite to experience a process of weathering and erosion or abrasion which erodes pre-existing primary tin deposits. The oxidation process and the influence of water circulation causes the breakdown of the primary tin ore constituents. The processes of weathering, erosion, transportation, and sedimentation of primary tin deposits produce secondary tin deposits. Based on the location of deposition, secondary tin deposits are divided into:

2.1.1. Alluvial deposits

This type of tin is deposited near the source rock so that it has large and angular grained physical characteristics.

2.1.2. collovial deposits
This type of tin is deposited on the slopes of a valley so that it has a slightly coarse and spiky grained physical characteristic.

2.1.3. alluvial deposits
This type of tin is deposited in valleys or riverbeds so that it has a undulating grained physical characteristic.

2.1.4. miencang deposits
This type of tin undergoes a selective deposition process repeatedly on certain lens-shaped layers so that it has the physical characteristics of being fine-grained and round.

2.1.5. Disseminated deposits
This type of tin is transported very far from the source rock and is spread very widely so that it has fine and irregular grained physical characteristics.

2.1.2. Regional Geology
The Bangka Islands are located in the western part of Indonesia, to be precise, in the east of Sumatra Island. Bangka Island is included in the Southeast Asian chain of origin known as the *Granite Tin Belt* (Figure 3) which is associated with the formation of tin that stretches from the Indo China-Peninsula, Thailand-Malaysia-Islands, Riau-Bangka Belitung Islands to West Kalimantan [5]. The Bangka Belitung Islands area is generally relatively flat, with undulating hills. The land surface of the mountains is relatively low with an altitude ranging from 100 to 500 meters above sea level which is used for plantation and tin mining businesses reaching ± 1,167,039 Ha. [6].

Bangka Island is an area with an advanced stage of erosion, this is characterized by generally relatively flat conditions and the presence of *monadrocks* . The hills left by erosion are composed of granite igneous rocks which generally occupy the edges of the island. In the north: the West-East oriented Klabat Granite passes through the Klabat bay, the surrounding granite consists of Pelangas granite, Klabat-Menumbing granite and Mangkol granite. In the south: Composed of smaller pluton namely Pluton Koba, Pluton Bebuluh, Pluton Permis, and Granite Toboali, as well as other plutons located in between. [1] Bangka Island was formed due to the collision between the Sibumasu Block and the Indochina Block which caused the formation of the Bentong Raub Suture. The Benong Raub Suture Zone is one of the best known deformation remnants of an accretionary complex that extended along the Malay Peninsula through the Indonesian tin islands, associated with Paleo-Tethys subduction and closure, followed by continental collisions during the Early Jurassic Triassic that limited the distribution of granitoids. [7] This Granitoid is 251-200 million years old (Late Permian-Late Triassic) by radiometric method.

[8] The bangka structure includes straightness, folds and faults. Alignment especially in granite with various directions. Folds are found in sandstone and claystone units. The structure formed was influenced by the collision process that occurred in the Permian-Triassic.

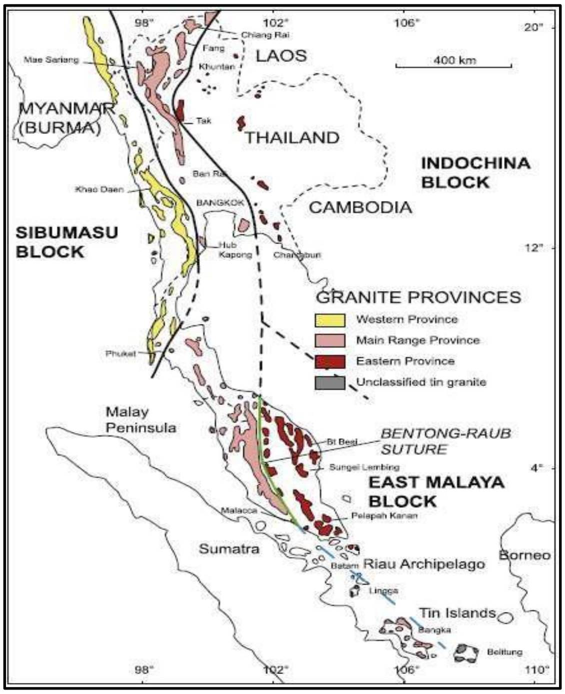

Figure 3. Southeast Asia's Tin Belt (Source: Cobbing, 1986)

2.1.3. Classification of Mineral Resources
Minerals are solid objects that are formed naturally from non-organic materials with a certain chemical composition. Estimation of mineral resources is carried out to determine the quantity and quality of these resources. The data used for estimating mineral resources is exploration data. Companies that carry out exploration must report the results of these activities in the form of resource reports by referring to the Indonesian National Standard (SNI) 4726: 2019 concerning guidelines for reporting exploration, resources and mineral reserves [9]. [10] According to SNI 4726:2019, mineral resources are divided into three groups, namely inferred resource groups, indicated resources, and measured resources.

First, an inferred mineral resource is a resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. This is estimated and assumed from the presence of geological evidence, but not verified geological continuity and grade. This is based solely on information obtained through adequate engineering of mineralized locations such as outcrops, test puritans, test wells and drill holes but limited or no quality and degree of confidence.

The maximum distance between observation points is two hundred meters. This space can be widened with technical justification.

Second, Indicated Mineral Resources Indicated mineral resources are mineral resources for which tonnage, density, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence. It is based on exploration results, and sampling sampling and testing information obtained through appropriate techniques from mineralized locations such as outcrops, test puritans, test wells, "test tunnels" and drill holes. The data collection locations are still too sparse or not properly spaced to ensure geological and grade continuity, but spatially sufficient to assume continuity. The maximum distance between observation points is one hundred meters. This space can be widened with justifiable technical justification such as geostatistical analysis.

Third, quantifiable mineral resources are mineral resources for which tonnage, density, shape, physical characteristics, grade and mineral content can be estimated with a high degree of confidence. It is based on detailed and reliable exploration results, and information on sampling and testing obtained by appropriate techniques from mineralized locations such as outcrops, test puritans, test pits, "test tunnels" and drill holes. The location of information in this category is spatially dense enough with a maximum spacing of fifty meters to ensure geological and grade continuity. This space can be widened with technical justification that can be accounted for, such as geostatistical analysis. The general relationship between the results of mineral resource exploration and mineral reserves can be seen in Figure 4.

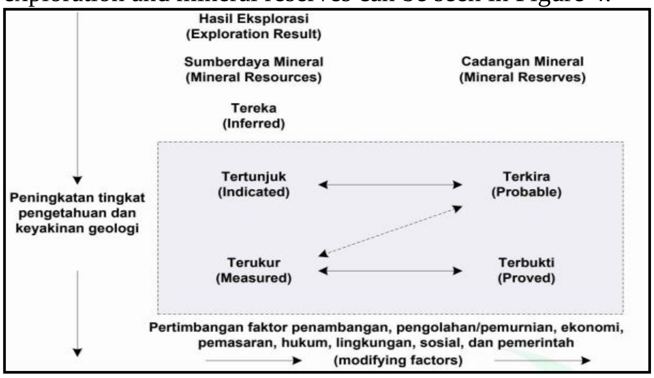

Figure 4. General Relationship Between Exploration Results, Mineral Resources and Mineral Reserves (Source: SNI 4726, 2011)

2.2. STUDY AREA

The research locations were Beliilik Village, Namang District and Menyak Village, Koba District, Central Bangka Administrative Region, Bangka Belitung Islands Province, more specifically the Mining Business Permit Area (WIUP) of PT Mitra Stania Bemban (MSB). PT MSB is a branch or subsidiary of PT Mitra Stania Prima (MSP) which has a WIUP in a different location from PT MSP's WIUP. From the city of Pangkal Pinang to the PT MSB office, it can be reached by four-wheeled vehicles, covering a distance of approximately 28 km. The condition of this road is an inter-city road which can be reached in approximately 30 minutes, then the journey continues from the PT MSB office to the Bemban site in Belilik village which is approximately 20 km away and takes approximately 60 minutes. The WIUP location consists of land and swamps due to its proximity to the sea.

2.3. SATELLITE DATASET

The data used in this study is PT MSB's drilling data which is secondary data. Drill point data in this study used as many as 230 points. The information needed is the information obtained from the drilling results, where the information obtained from the drilling results is the drill hole code, tin content, easting, northing, Altitude, Depth, and Slope. Qualitative data was obtained after analyzing drilling data in the laboratory.

The tin ore found in the study area consists of several layers of material or material zones, such as overburden, tin layers and bedrock. This data is then collected in tables containing data sets, which are then processed with MS. Excel then imports the data into the software for further evaluation.

III. METHODE

3.1.Inverse Distance Weighted (IDW)

Resource estimation is the ore deposit estimate which is part of the reserve calculation, which is the most important thing before proceeding to the next step. The choice of resource calculation method is based on the geological factors of the deposit. exploration method. Owned data. calculation purposes. and the desired level of confidence [11].

The IDW method is an evaluation method with a simple block model approach that takes into account the surrounding points. The assumption of this method is that the interpolated values are more similar to sample data that are closer than those that are more distant. The weights change linearly with the sample data spacing. The location of the sample data does not affect these weights. This method is often used in the mining industry due to its ease of use. The working principle of the IDW process is shown in Figure 5 below.

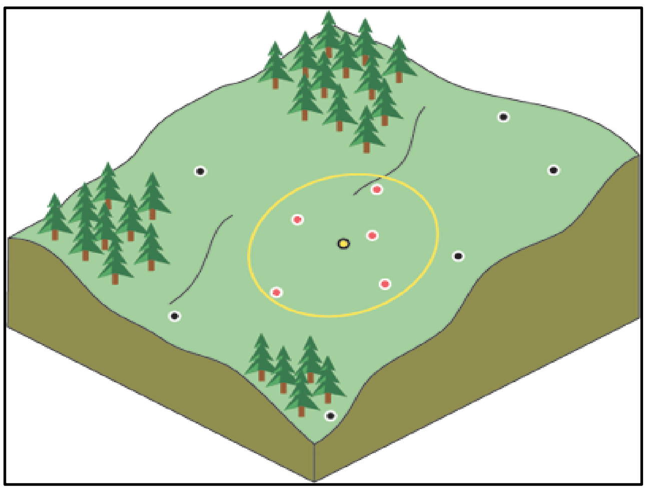

Figure 5. The Working Principle of the Inverse Distance Weighted (IDW) Method

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The selection of the operating power value greatly influences the interpolation results. Important factors that can affect the results of the assessment are the power and range of points or the amount of content information. The main factor that influences the accuracy of the estimation results is the value of the performance parameter, the emphasis is as follows [3].

$$w_i = \frac{\frac{1}{di^p}}{\sum_{i=1}^{n} \frac{1}{di^p}} \qquad (1)$$

To calculate the estimated point value, the following equation is used:

$$z_0 = \sum_{i=1}^{n} w_i \cdot z_i \qquad (2)$$

Information:

Z_0 : Estimated point value
W_i : The weight factor of the point
Z_i : The value of the estimating point
d_i : The distance between point i and the estimated point
p : Exponential factor (*power*)

3.2. *Nearest Neighbor Point* (*NNP*) *method*

In addition to the IDW method, resource estimation can also be carried out using the Nearest Neighbor Point method or the Nearest Polygon Method, where the value is obtained from the influence of each point on the closest or closest point. A point can be taken from the next point. The principle of this method is to consider the 1 point that is closest to the estimation point. The closest point has a weight of 1, while the farthest point has a weight of 0 or has no effect. The working principle of the NNP method can be seen in Figure 6. below:

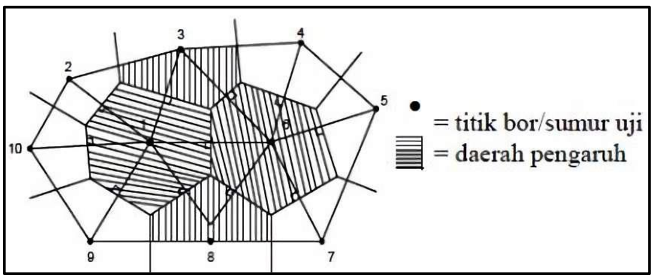

Figure 6. The Working Principle of the Nearest Neighbor Point (NNP) Method

IV. RESULTS AND DISCUSSION

The input data for this study are exploration drilling data and the output data are the quantity of resources shown in the following discussion:

4.1. Databases

The information received to estimate the resource is based on the results of ore prospecting carried out at mining operations under the supervision of PT Mitra Stania Bembani (MSB). The drill point data used in this study are 230 points. The information needed is information that comes from infill drilling results, where the information that comes from drilling results is ID Hole, depth, easting, northing, elevation, and slope. Qualitative data was obtained after analyzing drilling data in the laboratory. The tin ore found at the research site consists of several layers of material or material zones, such as the top layer, the coarse layer. After that, data will be collected in the data table in the form of a table, which is then processed with MS. Excel and then the data is imported into the software for further evaluation.

4.2. Data import

The existing drill data is input into the software to be used as a database , block modeling, and estimation of tin resources is carried out using the IDW and NNP methods. The results obtained are in the form of a three-dimensional drill point distribution which provides an overview of the distribution of ore grades and the shape of the ore deposit layer itself. The distribution of drill points is shown in Figure 7. The blue layer represents overburden , the orange color represents tin-containing wash and the yellow color is empty data or there is no data due to missing information.

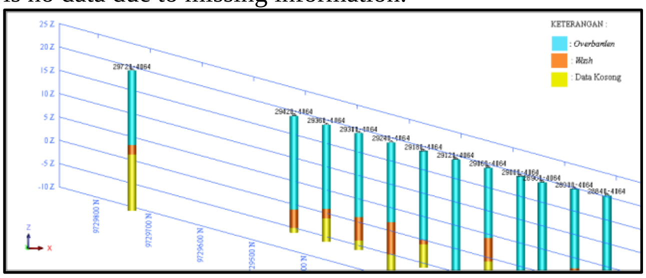

Figure 7. Drill Hole 3D View

Block modeling is the initial stage of evaluation which is used as a basis for interpolating the relationship between tin content between drill holes. The model block size used in this analysis uses a size of 40 x 40 x 1 M3 (length x width x height). Each block has an attribute in the form of a value that is used to calculate tin resources at PT MSB. The appearance of the model blocks and their cross sections is shown in Figure 8 and Figure 9.

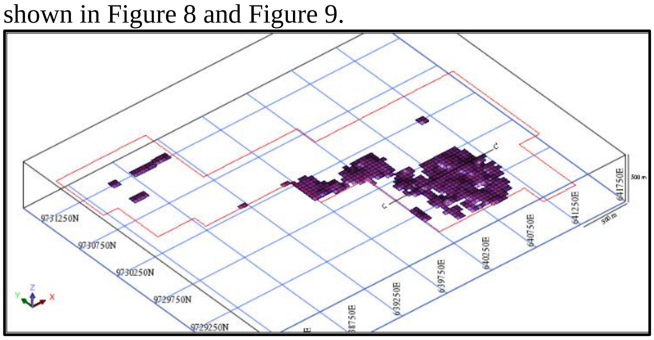

Figure 8. Block Model

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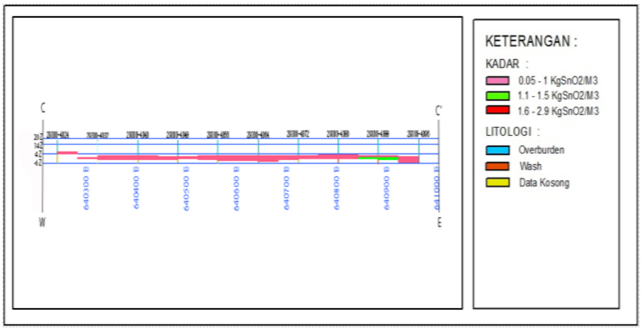

Figure 9. Section C-C'

4.3. Estimation Results Using the IDW Method

The biggest factor affecting the accuracy of IDW interpolation is the value of the *performance parameter* (p). The power value used in the assessment of resources in the study area is one. The results of the resource assessment are presented in Table 4.2. Resource estimation using the interpretation of a 100 meter radius (*Indicated Resource*) from the results of the assessment is grouped into three grade ranges from lowest to highest producing a total tonnage of Sn at an average *grade of 0.38 kg SnO2/m3 and a tonnage of 1,501s,300 tonnes of Sn.*

TABEL 2
RESOURCE ESTIMATION RESULT
USING THE IDW METHOD

Resource Estmation Using the IDW Method				
SnO2 Conten t Block	Volume	SnO2 Average Level	SnO2 tonnage	Sn. tonnage
	M3	KgSnO2/m 3	tons	tons
0.05 -> 1.0	3,486,40 0	0.37	1289.97	1,016,49 0
1.0 -> 1.5	36.8	1.16	42,69	33,64
1.5 -> 2.9	0	0	0	0
Total	3,523,20 0	0.38	1,332,66 0	1,501,30 0

4.4. Estimation Results Using the NNP Method

The resource estimates, grouped into three classes from lowest to highest, yield a total tonnage of Sn with an average grade of 0.83 kg SnO2/m3 and 1,270,222 tonnes of Sn. The results of the evaluation of resources are presented in Table 3 below:

TABEL 3
RESOURCE ESTIMATION RESULT
USING THE NNP METHOD

Resource Estmation Using the IDW Method				
SnO2 Conten t Block	Volume	SnO2 Average Level	SnO2 tonnage	Sn. tonnage
	M3	KgSnO2/m 3	tons	tons
0.05 -> 1.0	2,820,80 0	0.52	1,119,38 6	873,121
1.0 -> 1.5	308,800	1,2	364,880	284,606
1.5 -> 2.9	65,600	2,29	144,224	112,494
Total	3,195,20 0	0.83	1,628,49 0	1,270,22 2

4.5. Comparison of Estimation Results Using IDW and NNP Methods

After calculating the resources, there are differences between the results of the assessment of the IDW and NNP methods, which are shown in Table 4. The estimation results between the two methods have different estimation values. Therefore, it is necessary to calculate the percentage difference in the estimation results using these two methods.

TABEL 4
RESOURCE ESTIMATION RESULT
USING THE IDW METHOD

Estimation Method	Volumes (M3)	Tonnage (Tons)	Average Content (%)
Inverse Distance weighted (IDW)	3,523,200	1,050,130	0.38
Nearest Neighbor Point (NNP)	3,195,200	1,270,222	0.83

From the table above it can be seen that it is estimated that there is a difference of 231.078 tons between the two methods used. The difference between these results is 18% using equation (1) below.

$$\%Selisih = \frac{TonaseTertingi - TonaseTerendah}{TonaseTertinggi} x100\%$$

$$\%Selisih = \frac{1.270.222ton - 1.501.300ton}{1.270.222ton} X100\% = 18\%$$

[12] The factor causing the difference in the results of the resource estimation using the two methods is the number of influence points in the block. IDW method calculations based on the data point closest to the point being evaluated are given more weight than data points that are farther away. This method is based on point estimation and does not depend on block size and only considers distance and does not take into account the effect of data grouping, so that data given the same distance but with different distribution patterns still give the same results. When calculating with the NNP method, points take into account the value based on the closest block or point. So the NNP method takes into account one closest point, while the IDW method takes into account several closest points.

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V. CONCLUSION

PT MSB's tin inventory is 1,501,300 tons using the IDW method and 1,270,222 tons using the NNP method. The difference between the two methods is 231.078 tons with a percentage of 18%. This is due to the working principle of the two methods, namely the IDW method considers several closest points while the NNP method considers the closest point.

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REFERENCES

[1] Barber, AJ, Crow, MJ, Milsom, JS 2005. Sumatra: Geology, Resources

[2] Law Number 3 of 2020

[3] Grace, Dodi. S, 1987, Rocks and Minerals, Nova, Bandung.

[4] Nurhakim, S. 2022. Estimation of Tin Resources in Alluvial Deposits in the Menduk Area, Kab. Bangka, Prov. Kep. Bangka Belitung

[5] Cobbing, EJ, Mallick DIJ, Pitfield PEJ, and Teoh LH 1986. *The Granite of Southeast Asian tin belt, Journal of the Geological Society* .

[6] BPS Prop. Babel, "Bangka Belitung Province in Figures 2019", Central Bureau of Statistics (BPS) Bangka Belitung Province, 2019

[7] Schwartz, MO, Rajah, SS, Askury, AK, Putthapiban, P., and Djaswadi, S. 1995: *The Southeast Asian tin belt, Elsevier* .

[8] Margono, U., Supandjono, RJB, and Partoyo, E. (1995): Geological Map of the South Bangka Sheet, Scale 1:250,000, Geological Development Research Center, Bandung.

[9] SNI 4726, 2011 Guidelines for Reporting Mineral Resources and Reserves.

[10] SNI 4726, 2019 Guidelines for reporting exploration results, resources and mineral reserves.

[11] Maharza, C., & Octova, A. (2018). Estimation of Coal Resources Using the Cross Section Method in Pit 2 PT. Tambi Hill Mine. Padang Kelapa site. district Muaro Sebo Ulu. Regency. Batanghari. Jambi Province. *Mining Bina* , *3* (4), 1793-1803.

[12] Zibuka, MI (2016). Estimating Laterite Nickel Resources By Comparing Nearest Neighbor Point Methods And Inverse Distance Weighting. *Geomine Journal* , *4* (1).

[1]