

Interpolation of Total Dissolved Solids (TDS) Concentration in A River Using Ordinary Kriging Method

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ABSTRACT

Water quality is a key indicator related to the sustainability of living things in a watershed. However, human activities have led to a decline in the water quality caused by industrial, domestic and agricultural waste. This study aims to predict the pattern of TDS parameters at unsampled points through a geostatistical approach, namely Kriging. Experimental measurements were conducted in the Bedadung River, Jember Regency, especially in a segment of Patrang to Wuluhan sub-districts. Currently, the river is classified as Class 3, which is below the standard, one of the water quality parameters is TDS (Total Dissolved Solid). The TDS estimation results were obtained in the range of 48.26 mg/L - 175.52 mg/L. The predicted value of TDS using the kriging method at unsampled points resulted in an RRMSE value of 8.40 %. This study revealed that the water quality of Bedadung River from Patrang to Wuluhan sub-districts was still below Class 2 standards, emphasizing the need for continuous monitoring and improvement efforts.

1. INTRODUCTION

Water quality is one of the most important components of the environment and an indicator of the health of a watershed (Setyowati, 2015). Various anthropogenic activities and utilisation of water resources can produce waste contributions that affect the decline in river water quality. According to Novita *et al.* (2023), the current water quality status of Bedadung River is still in the third class, which means that it is not in accordance with its designation. This is due to the discharge of industrial waste, household waste, agricultural waste into the river body. The biggest contribution to environmental damage is from human actions themselves, this is due to the lack of human concern for environmental damage. A river is defined as polluted if its water quality conditions do not meet the specified requirements (Pohan *et al.*, 2016). In general, pollution is the entry of a substance or other component into the environment caused by natural processes or human activities resulting in decreased environmental quality which results in the environment becoming degraded and ultimately unable to function as it should (Pangestu *et al.*, 2017). Therefore, it is necessary to monitor the condition of river water quality.

One of the measurements of water quality level can be seen from water quality parameters, namely Total Dissolved Solid (TDS). This study uses the TDS parameter because in certain areas there are residential and agricultural areas, where both areas have waste contributions that have a significant effect on increasing the TDS value. TDS has an important role as an indicator of determining river water quality. High TDS values can interfere with organisms in the water because the water is toxic and makes water quality less (Chuzaini & Dzulkiflih, 2022). The higher the TDS value, the lower the water quality in a water body. TDS measurements are carried out only at several points due to limited time and cost if carried out at all points, so it is necessary to make observations using other methods to be able

to estimate TDS levels at several unsampled points. One method to determine water quality at unsampled points is to use the Ordinary Kriging method.

The Ordinary Kriging method is applied because it uses spatial values at sampled locations and variograms that show the correlation between spatial points to predict values at unsampled locations. Ordinary Kriging is the most widely used Kriging method. The advantages of this method in estimating river water TDS values are that it is more efficient in terms of time, cost and researcher safety, because it does not need to take samples in the field and does not need to analyse in the laboratory, and can prioritise researcher safety because at some points there are rocky streams, this can make it difficult for researchers to take samples.

This study aims to analyse the water quality of Bedadung River using the TDS parameter at unsampled points. TDS is an indicator that measures the amount of solids or particles dissolved into water (Putri *et al.*, 2024). The results of the estimation are then compared with the specified quality standard, namely, the water quality standard Appendix VI of PP No. 22 of 2021 concerning the Implementation of Environmental Protection and Management. The results of determining the quality status can be an input in making a decision in order to assess water quality for a designation and become a guideline in improving water quality if there is a decrease in water quality due to pollutants.

2. MATERIALS AND METHODS

2.1. Tools and Materials

This research was conducted in Bedadung River, Jember Regency, East Java. Bedadung River is the largest river in Jember Regency. Bedadung River has a length of about 161 kilometres and flows from the slopes of Mount Hyang and empties into Dampa Bay, Indian Ocean near Puger (Figure 1). Bedadung River passes through 17 sub-districts in Jember Regency (Wahyuningsih *et al.*, 2019). Many people in Jember Regency utilise the Bedadung River for their daily lives. Based on data from the BPS (2023), Jember Regency has a population of 2.58 million people. The activities carried out by the community in Bedadung River, among others, are for agricultural irrigation activities, toilets, fishing and so on, which in principle are all for human needs all the time. This research was conducted in Bedadung River, Jember Regency, East Java based on secondary data obtained from previous researchers as presented in Table 1 and other secondary data such as spatial data shp province, shp district, shp sub-district, shp watershed boundaries, shp river can be downloaded through the GIS website while spatial data RBI map can be downloaded through the website <https://tanahair.indonesia.go.id/>. Research was done in January - March 2024. The instruments used in this research are Laptop, software Microsoft Word 2021, software Microsoft Excel 2021, software ArcGIS 10.8.

Table 1. Source data from previous researchers

OP	Location	Coordinate		TDS (mg/L)	OP	Location	Coordinate		TDS (mg/L)
		Longitude (X)	Latitude(Y)				Longitude (X)	Latitude(Y)	
1	Atokan 1	113.7868282	-8.06427078	134.4	15	Ajung 3	113.649263	-8.205641	132.4
2	Atokan 2	113.7849151	-8.06564187	144.2	16	Ajung 4	113.648502	-8.206335	132.7
3	Atokan 3	113.7828948	-8.06611659	131.6	17	Gayam 1	113.6131530	-8.2156830	76.4
4	Atokan 4	113.7801405	-8.06876880	134.8	18	Gayam 2	113.6077050	-8.2182690	83.2
5	Arjasa 1	113.747770	-8.122185	63	19	Gayam 3	113.6068750	-8.2189930	81.1
6	Arjasa 2	113.747976	-8.127556	64.1	20	Gayam 4	113.6054550	-8.2194250	77.4
7	Arjasa 3	113.745971	-8.130412	64.1	21	Kaliwining 1	113.627187	-8.203228	107.4
8	Arjasa 4	113.742960	-8.133496	64.7	22	Kaliwining 2	113.627484	-8.206228	109.2
9	Kaliwates 1	113.6733274	-8.18306498	48	23	Kaliwining 3	113.627094	-8.209251	102.6
10	Kaliwates 2	113.6739474	-8.18424354	48.6	24	Kaliwining 4	113.627775	-8.210383	103.9
11	Kaliwates 3	113.6742236	-8.18620491	48.7	25	Rowotamtu 1	113.586230	-8.2119060	56.56
12	Kaliwates 4	113.6742044	-8.18815135	49.6	26	Rowotamtu 2	113.5872217	-8.2139559	55.33
13	Ajung 1	113.659526	-8.207226	131.7	27	Rowotamtu 3	113.5887610	-8.2158240	55.89
14	Ajung 2	113.652520	-8.205399	131.6	28	Rowotamtu 4	113.5908460	-8.2180650	57.22

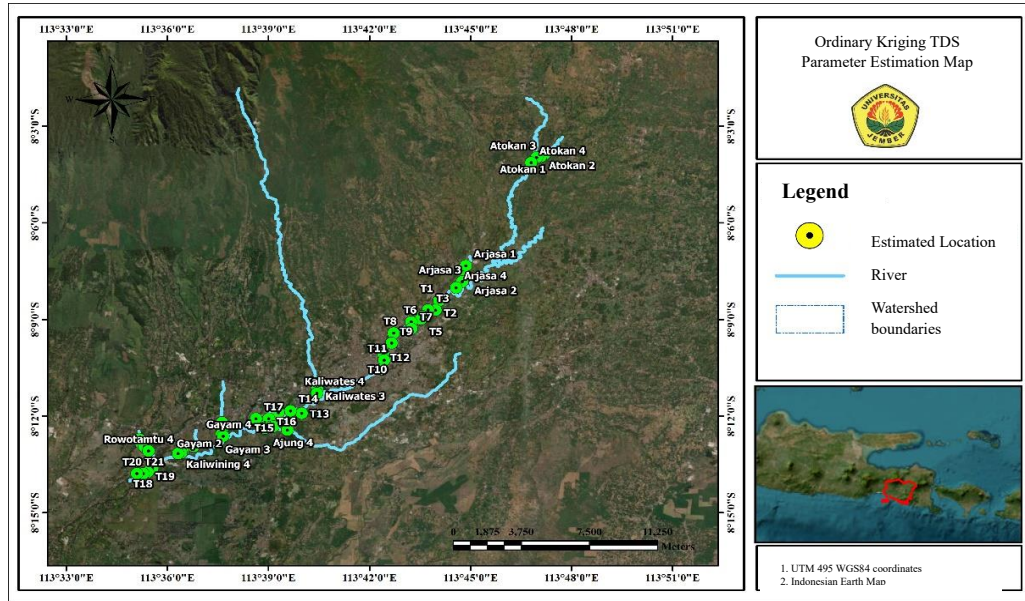


Figure 1. Map of the study area

2.2. Ordinary Kriging Method

2.2.1. Estimation Calculation TDS

The determination of the estimation value in this study uses the Ordinary Kriging method. This method is used to determine the estimation value of TDS parameters of Bedadung River. The calculation process was carried out using ArcGIS 10.8 software and the calculation stages of the Ordinary Kriging method are as follows.

1) Experimental Semivariogram. Experimental semivariogram used the following equation:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} (Z(s_i) - Z(s + h))^2 \quad (1)$$

where $\gamma(h)$ is value of semivariogram with distance h , $Z(s_i)$ is the observed value at location, $Z(s + h)$ is the observed value at the location with the addition of distance h , and $N(h)$ is the number of pairs of points that have a distance h (Sari *et al.*, 2019).

2) Theoretical Semivariogram. In the theoretical semivariogram, there are 3 models, namely spherical, exponential, and Gaussian. The 3 models were presented in the following equations:

a. Spherical model:

$$\gamma(h) = \begin{cases} C_0 + C \left[\left(\frac{3h}{2a} \right) - 0,5 \left(\frac{h}{a} \right)^3 \right] & \text{for } h \leq a \\ C_0 + C & \text{for } h > a \end{cases} \quad (2)$$

b. Exponential model:

$$\gamma(h) = C_0 + C \left[1 - \exp \left(-\frac{3h}{a} \right) \right] \quad (3)$$

c. Gaussian model:

$$\gamma(h) = C_0 + C \left(1 - \exp \left(-\frac{h^2}{a^2} \right) \right) \quad h \neq 0 \quad (4)$$

where C_0 is value of nugget effect, $C_0 + C$ is value from sill effect, a is value of range, and h is distance of sample location (Rohma, 2022).

3) Cross Validation. After testing the three models, namely spherical, exponential, and Gaussian, cross validation is carried out. Cross validation aims to test the selected model based on the Root Mean Square Error (RMSE) value:

$$RMSE = \sqrt{\sum \frac{(Y' - Y)^2}{n}} \quad (5)$$

where Y' is predicted value, Y is actual value, and n is number of data (Rohma, 2022).

3. RESULTS AND DISCUSSION

3.1. Data Description

The data used in this research is river water quality data using one parameter, TDS, obtained from previous researchers with 49 measurement points in Bedadung River. The data that has been obtained is presented in Table 2.

3.2. TDS Interpolation

Estimation is done using ArcGIS 10.8 software. The data used at this stage are TDS parameter value data and point coordinate data that have been obtained from previous researchers. The first thing that needs to be done when doing Ordinary Kriging interpolation is to form an experimental semivariogram (semivariogram cloud). The shape of the TDS parameter water quality data semivariogram cloud is presented in Figure 2.

Table 2. Bedadung River water quality data TDS parameter

OP	Location	Coordinate		TDS (mg/L)	OP	Location	Coordinate		TDS (mg/L)
		Long. (X)	Lat. (Y)				Long. (X)	Lat. (Y)	
1	Baratan	113.73465	-8.140177	168	26	Arjasa	113.74777	-8.122185	63
2	Baratan	113.73288	-8.145127	168.67	27	Arjasa	113.74798	-8.127556	64.1
3	Patrang	113.72914	-8.145087	171	28	Arjasa	113.74597	-8.130412	64.1
4	Patrang	113.72635	-8.148359	170.67	29	Arjasa	113.74296	-8.133496	64.7
5	Patrang	113.72565	-8.149749	172	30	Kaliwates	113.67333	-8.183065	48
6	Patrang	113.72073	-8.15123	174.67	31	Kaliwates	113.67395	-8.1842435	48.6
7	Tegal Gede	113.72092	-8.154715	174	32	Kaliwates	113.67422	-8.1862049	48.7
8	Sumbersari	113.71214	-8.157025	121.33	33	Kaliwates	113.6742	-8.1881514	49.6
9	Sumbersari	113.7111	-8.162177	120.67	34	Rambipuji	113.61315	-8.215683	76.4
10	Sumbersari	113.70689	-8.167814	123.67	35	Rambipuji	113.60771	-8.218269	83.2
11	Sumbersari	113.70744	-8.171041	129	36	Rambipuji	113.60688	-8.218993	81.1
12	Sumbersari	113.70635	-8.175804	125.67	37	Rambipuji	113.60546	-8.219425	77.4
13	Ajung	113.66661	-8.198487	122.67	38	Kaliwining	113.62719	-8.203228	107.4
14	Ajung	113.66114	-8.197299	125	39	Kaliwining	113.62748	-8.206228	109.2
15	Ajung	113.6551	-8.198173	125.67	40	Kaliwining	113.62709	-8.209251	102.6
16	Ajung	113.6503	-8.20134	126.33	41	Kaliwining	113.62778	-8.210383	103.9
17	Ajung	113.64402	-8.202156	129.33	42	Rowotamtu	113.58623	-8.211906	56.56
18	Rowotamtu	113.59271	-8.22704	102.89	43	Rowotamtu	113.58722	-8.2139559	55.33
19	Rowotamtu	113.59031	-8.228971	107	44	Rowotamtu	113.58876	-8.215824	55.89
20	Rowotamtu	113.58826	-8.229788	106.78	45	Rowotamtu	113.59085	-8.218065	57.22
21	Rowotamtu	113.58501	-8.229714	107.56	46	Ajung	113.65953	-8.207226	131.7
22	Sukowiryo	113.78683	-8.0642708	134.4	47	Ajung	113.65252	-8.205399	131.6
23	Sukowiryo	113.78492	-8.0656419	144.2	48	Ajung	113.64926	-8.205641	132.4
24	Sukowiryo	113.78289	-8.0661166	131.6	49	Ajung	113.6485	-8.206335	132.7
25	Sukowiryo	113.78014	-8.0687688	134.8					

Note: OP = Observation Point

Based on Figure 2 above, researchers have difficulty in seeing patterns because it has many observation points, so it is necessary to group them by distance (binning). Binning is a technique of changing data by converting data into a smaller scale (Mälicke, 2022). Below are the results of the theoretical semivariogram using 3 models namely spherical, exponential, and Gaussian presented in Figures 3, 4, and 5. Based on the figures, the red coloured points are binned points at each lag, while the blue coloured points are binned averages at each lag.

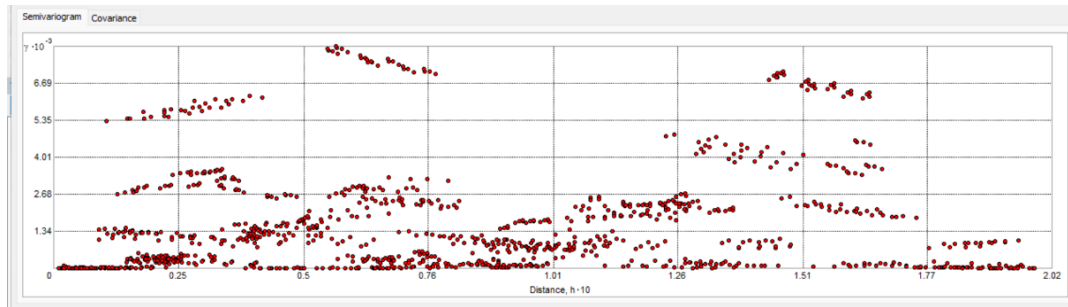


Figure 2. Semivariogram of Bedadung River water quality data cloud for TDS parameter

3.3. Cross Validation

Comparing the experimental and theoretical semivariogram results, with the aim of obtaining the best theoretical model. In determining the best theoretical semivariogram, it is determined based on the Root Mean Square Error (RMSE) value. Root Mean Square Error (RMSE) is a method to assess an estimation technique used in measuring the accuracy of the estimation results of a model (Ruswanti, 2020). RMSE has a high level of accuracy in making measurements with a probability of up to 50% (Wijaya *et al.*, 2023). The RMSE value is obtained from the difference between the sample observation data in the field and the estimation results of each model which are then calculated according to the equation.

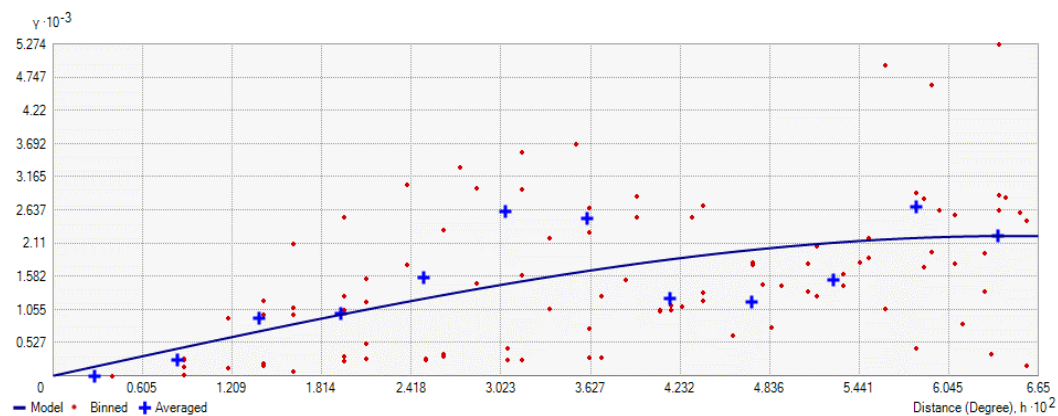


Figure 3. Spherical model theoretical semivariogram

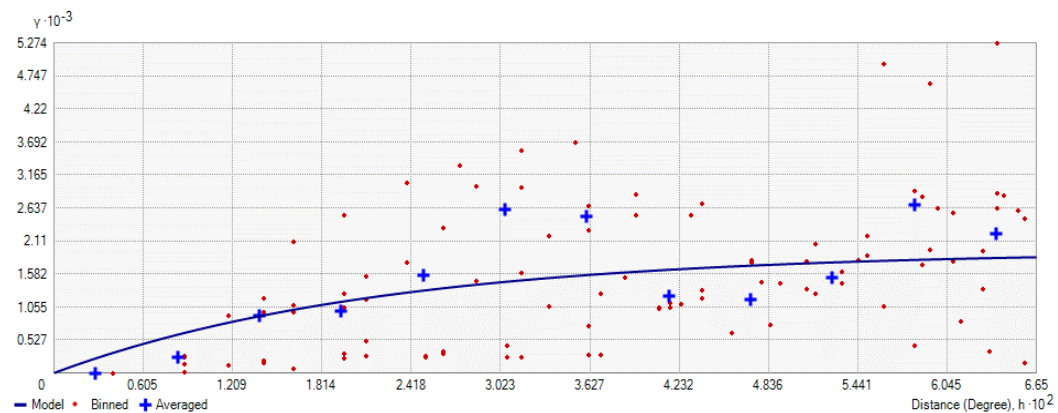


Figure 4. Exponential model theoretical semivariogram

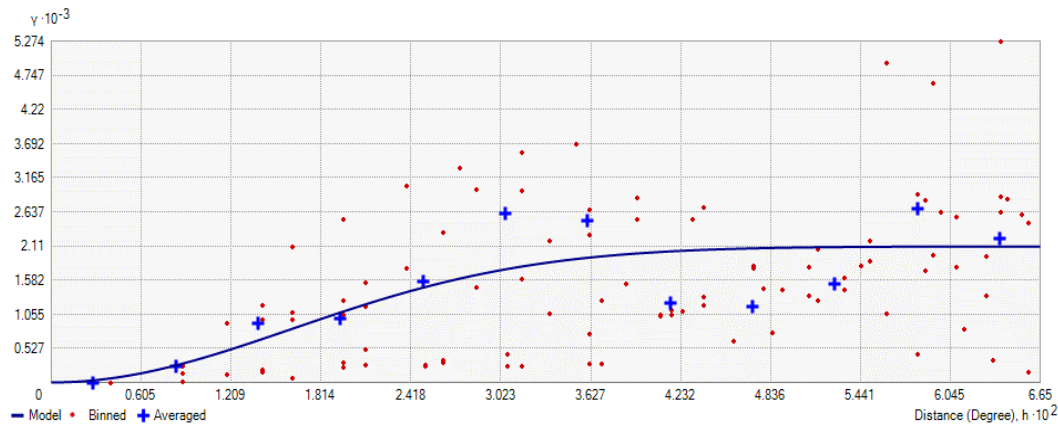


Figure 5. Theoretical semivariogram of the Gaussian model

It can be seen from Table 3 above that each model has a different RMSE value. The smallest amount of error of the three models is in the spherical model with a value of 8.40. This is in accordance with the study by [Hamdanah & Fitrihanah \(2021\)](#), if the RMSE value is smaller or closer to zero, the prediction results are more accurate ([Arinal & Azhari, 2023](#)). Therefore, it is concluded that the best model for the Ordinary Kriging method is the spherical model.

Table 3. RMSE values of three semivariogram models

No.	Model Semivariogram	RMSE Value
1.	<i>Spherical</i>	8.40
2.	<i>Exponential</i>	8.81
3.	<i>Gaussian</i>	10.35

3.4. TDS Value Distribution Results

The creation of the distribution map was carried out using ArcGIS 10.8 software with the geostatistical analyst tool. The distribution map of river water quality using TDS parameters using the best theoretical semivariogram model, namely the spherical model. The spherical model was chosen because it has the smallest RMSE value. The following is a distribution map using the spherical semivariogram presented in Figure 6. Based on Figure 6, it shows that the TDS estimation results in Bedadung River are between 48.26 mg/L - 175.52 mg/L. The results of the TDS estimation are still below the quality standard value, which is below 1000 mg/L. Although it is below the quality standard value, there is an increase in the TDS value at the 1st and 14th estimation points. This is because the location is in an urban area which means that there are many human activities and discharges into the river so that it can affect the increase in TDS. The high content of dissolved solids in water can be influenced by natural factors from rock weathering, as well as anthropogenic activities from industrial and agricultural activities ([Kiffly *et al.*, 2021](#)). According to [Pradana *et al.* \(2019\)](#), if the TDS value is high, it is not suitable for use as a raw water source because it poses a risk of health problems when used as a clean water source. The more dissolved substances in the water, it will have a negative impact on the ecosystem and disrupt the balance of the waters ([Aguatin & Rijal, 2024](#)).

3.5. Comparison of Water Quality Status with Second Class Quality Standard

The results of the TDS concentration estimation carried out in Bedadung River presented in Figure 6 show the TDS concentration value ranging from 48.26 mg/L - 175.52 mg/L. Based on Appendix VI of Government Regulation No. 22 of 2021 on the second class quality standard, the TDS estimation carried out in Bedadung River is known to be still below the second class quality standard so that it is still in accordance with the second class designation, namely as facilities and infrastructure, recreation, fish farming, animal husbandry, and crop irrigation. According to PP No. 22 of 2021, the quality standard of the second class TDS parameter value is a maximum of 1000 mg/L. The decrease in TDS

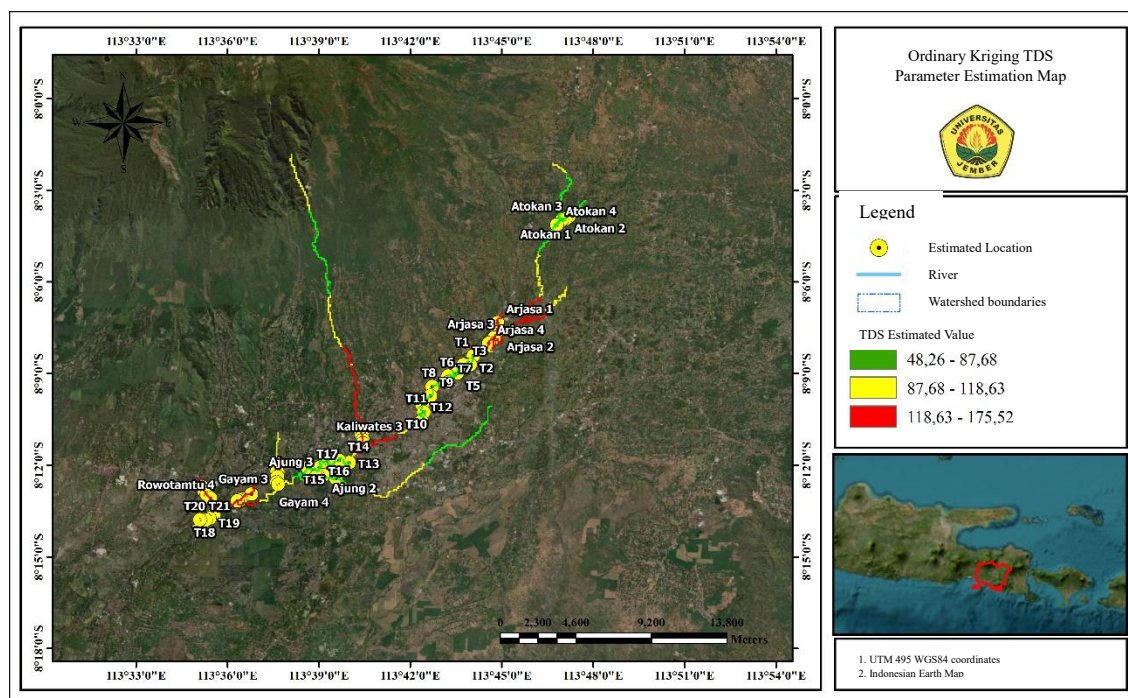


Figure 6. Scatter map using experimental semivariogram

levels at the study site is related to the amount of waste input discharged to the study site and the ability of the river to carry out a natural purification process (selfpurification). This is in accordance with the study by [Wahyuningsih et al. \(2020\)](#), a decrease in pollutant indicators indicates that the river has the ability to recover naturally (selfpurification) from excess contaminants. Selfpurification is the ability of a water body to remove organic matter, plant nutrients, or other contaminants from a lake or river by the biological activity of the community living inside ([Arbie et al., 2015](#)).

4. CONCLUSION

The results of the estimation of the TDS parameter value in Bedadung River show a value that is close to the measurement results at the location of the sample point, because the calculation of the RMSE of the spherical semivariogram model produces a value of 8.40, which means that the ability of the forecasting model is feasible to estimate TDS and the resulting TDS estimation value with a range of 48.26 mg/L - 175.52 mg/L. The results of the comparison of the estimated TDS value with the river water quality standards of PP No. 22 of 2021 have met the second class quality standards so that they are still in accordance with the second class designation, namely as facilities and infrastructure, recreation, fish farming, animal husbandry, and crop irrigation.

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