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Inverse Distance Weighted Methods in Groundwater Modelling Ponjong Area, Gunung Kidul Regency, Special Region of Yogyakarta, Indonesia

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ABSTRACT

Groundwater modeling is needed to display the underground dimensions of groundwater. The Inverse Distance Weighting (IDW) technique is the choice as the basis for groundwater model analysis because the analysis using this technique remains accurate even though it only uses a few sample points. The groundwater model in Sidorejo Village, Ponjong District, Gunungkidul Regency, Yogyakarta Special Region has a water thickness of between 4.5 – 13.85 meters. With a pore aquifer system, because based on data from field observations and interpretation of geological maps, Sidorejo village, Ponjong District, Gunungkidul Regency, Yogyakarta Special Region is included in the Wonosari formation with geological structures in the form of limestone, reef, calcarenite, calcarenite tuffan. As for the direction of groundwater flow to the west, following the slope of the slope found at the study site. While the results of groundwater quality analysis using the Inverse Distance Weighting (IDW) technique by testing several parameters including the degree of acidity (pH), electrical conductivity (DHL), Total Disolved Solid (TDS), iron (Fe), calcium (Ca) , magnesium (Mg), and calcium carbonate (CaCO3) it can be concluded that all test well samples indicated no contamination because all test parameters were still within normal limits.

Keywords: Groundwater, Groundwater Modelling, Inverse Distance Weighted (IDW)

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ABSTRACT

Pemodelan airtanah diperlukan untuk menampilkan dimensi bawah tanah airtanah. Teknik Inverse Distance Weighting (IDW) menjadi pilihan sebagai dasar analisis model air tanah karena analisis menggunakan teknik ini tetap akurat meskipun hanya menggunakan beberapa titik sampel. Model air tanah di Desa Sidorejo, Kecamatan Ponjong, Kabupaten Gunungkidul, Daerah Istimewa Yogyakarta memiliki ketebalan air antara 4,5 – 13,85 meter. Dengan sistem akuifer pori, karena berdasarkan data observasi lapangan dan interpretasi peta geologi, Desa Sidorejo, Kecamatan Ponjong, Kabupaten Gunungkidul, Daerah Istimewa Yogyakarta termasuk dalam formasi Wonosari dengan struktur geologi berupa batugamping, karang, kalkarenit, tufan kalkarenit. Adapun arah aliran airtanah ke arah barat mengikuti kemiringan lereng yang terdapat di lokasi penelitian. Sedangkan hasil analisis kualitas airtanah menggunakan teknik Inverse Distance Weighting (IDW) dengan menguji beberapa parameter antara lain derajat keasaman (pH), daya hantar listrik (DHL), Total Disolved Solid (TDS), besi (Fe), kalsium (Ca).) , magnesium (Mg), dan kalsium karbonat (CaCO3) dapat disimpulkan seluruh sampel sumur uji tidak terdapat kontaminasi karena seluruh parameter pengujian masih dalam batas normal.

Keywords: Air Tanah,Muka Air tanah, IDW

INTRODUCTION

Gunung Kidul Regency is a karst area located in the Province of the Special Region of Yogyakarta. The karst area is an area with a characteristic morphology with a basin in it, the basin is a drainage caused by the intensive dissolution of its rocks (Ford and Williams, 1989)[1]. The karst area has hydrological conditions that are different from hydrological conditions in other areas [2]. The hydrological conditions in the karst area have a multibasinal flow system with secondary porosity. Thus giving rise to subsurface tunnels and subsurface rivers [3]

The characteristics of the water in the karst area can be seen through its drainage system. The aisle groundwater flow system in the karst area can be divided into three, namely diffuse flow, fissure flow, and conduit flow. These alleys which, when filled with water, will form underground rivers whose existence is not evenly distributed in all directions (anisotropic)[4]. Groundwater flow systems in karst areas formed by rock fractures due to geological structures and rock dissolution. The type of porosity in karst is secondary porosity which has an anisotropic nature with an irregular groundwater table and distributed groundwater flow in all directions [5].

In this regard, it is necessary to have a more in-depth hydrogeological study regarding resources in the form of groundwater in terms of quantity and quality. It can be used as food for thought in the business of optimally processing and developing water resources for the local government[6]. Therefore the writer is interested in conducting research on groundwater in Sidorejo Village, Pojong District, Gunung Kidul Regency, Yogyakarta Special Region as the object of this research[7].

METHOD

The geostatistical method is an estimation of sample values that are well known where this term was used for the first time by G. Matheron (1962) and is defined as the application of random relations or derivative functions in studying and predicting natural phenomena where certain variables can be identified. Variables are measured depending on the surrounding values distributed in 2D and 3D[8]. Where the variables are tests of different f(x) functions at the point distance (x) in that space. In this geostatistical method, several terms are used which are calculations in estimation as the basis for estimating the reserves of the geostatistical method, including the following:

Isotropy

The variograms in various directions are the same, which means that γ(h) are absolute values h. if the prices at the distance of influence are plotted in a cartesius diagram, the range is the same distance and produces an image resembling a circle.[9]

Geometry Anisotropy

The distance of influence in the four directions (0°, 45°, 90°, 135°) results in different distance values, where the four values are plotted onto a cartecius axis and will produce an elliptical shape, which in geostatistics is called anisotropy. In anisotropy, this geometry can be characterized by the presence of the same nugget, effect, sill, while the range of influence varies in plotting.[10]

Estimation Variance

The estimation variance is the variance of the errors that occur in estimating the sample value shown in the examples inside the block and the area around the block or it can be said that the estimated variance is the actual estimated value with the estimate where there is a difference which is the difference in estimates. [5] The estimation variance is the variance of the errors that occur in estimating the sample value shown in the examples inside the block and the area around the block or it can be said that the estimated variance is the actual estimated value with the estimate where there is a difference which is the difference in estimates.

The following is the basic equation for the estimated variance expressed by:

$$\sigma^2 E = 2\,\gamma(v.V) - \gamma(V.V) - \gamma(v.v) \quad \text{.......(i)}$$

Information :

σ^2 E = Estimated variance

γ (v.V) = Represents the average value of $\gamma(h)$ if one end of the vector h represents the V(x) domain or block, while the other end indicates the v(x) domain or point.

γ (V.V) = Stating the average value of $\gamma(h)$ if one end of the vector h shows the domain V(x) and the other end of the vector shows the domain V(x) too.

γ (v.v) = Stating the average value of $\gamma(h)$ if one end of the vector h shows the V(x) domain, while the other end shows the v(x) domain as well.

Inverse Distance Weighting (IDW)

The Inverse Distance Weighted (IDW) method is a simple deterministic method by that considering the surrounding points. The assumption of this method is that the interpolation values will be more similar to the sample data that are closer than those that are farther away. The weight will change linearly according to the distance from the sample data. This weight will not be affected by the location of the sample data. This method is usually used in the mining industry because it is easy to use. The selection of the power value greatly affects the interpolation results. A high power value will give results like using nearest neighbor (NNP) interpolation where the value obtained is the value of the nearest data point. The disadvantage of the IDW method is that the interpolated value is limited to the values in the sample data. The influence of the sample data on the interpolation results is called isotropic. In other words, because this method uses the average of the sample data, the value cannot be less than the minimum or greater than the sample data. Thus, the peaks of hills or the deepest valleys cannot be displayed from the interpolation results of this model.

To get good results, the sample data used must be closely related to local variations. If the samples are sparse and uneven, the results are likely not to be what one would like. The IDW method can be calculated using the following formula:

$$Z = \frac{\sum_{i=1}^{n} \frac{1}{di^{k}} x\ zi}{\sum_{i=1}^{n} \frac{1}{di^{k}}} \qquad \text{(ii)}$$

Information :

Ż : Estimated point value

di : The distance point i

k : *Power* (1,2,3,…., n).

zi : The value of estimator point

In general, the Inverse Distance Weighting method is as follows (Latif, 2008):

1. Estimation of reserves in a way where the average price of the estimated point is a linear combination or weighted average of the drill hole data around that point. Data near the estimated point gets greater weight, while data far from the estimated point gets less weight. This weight is inversely proportional to the distance of the data from the point being estimated.

2. The choice of rank used (ID1, ID2, ID3,…) affects the estimation results. The higher the rank used, the results will be to the better results. The IDW method can be explained by the following formula:

a) *Inverse Distance*

$$Wi = \sum_{i=1}^{n} \left(\frac{Zi}{Di}\right) \ atau \sum_{i=1}^{n} \left(\frac{1}{Di}\right)$$

b) *Inverse Square*

$$Wi = \sum_{i=2}^{n} \left(\frac{Zi}{Di}\right) \ atau \sum_{i=2}^{n} \left(\frac{1}{Di^2}\right)$$

c) *Inverse Distance Cubic*

$$Wi = \sum_{i=3}^{n} \left(\frac{Zi}{Di}\right) \ atau \sum_{i=3}^{n} \left(\frac{1}{Di^3}\right)$$

Information :
Wi = Factor data weighted grid i
di = Distance grid i with the estimated grid.
n = Exponen Factor.
Result Estimate Z :

$$Z = \sum_{i=1}^{n} w_i . Z_i \quad \text{(iii)}$$

The method used in this study is a quantitative and qualitative research method where this research is related to applied science. Data collected in this study is in the form of rainfall data for the last ten years and water level. After the data is collected, the next stage is to process the data to find out the average amount of rainfall and calculate the number. The scope of groundwater quality research carried out in Sidorejo Village, Ponjong District, Gunungkidul Regency, Special Region Province, Yogyakarta.

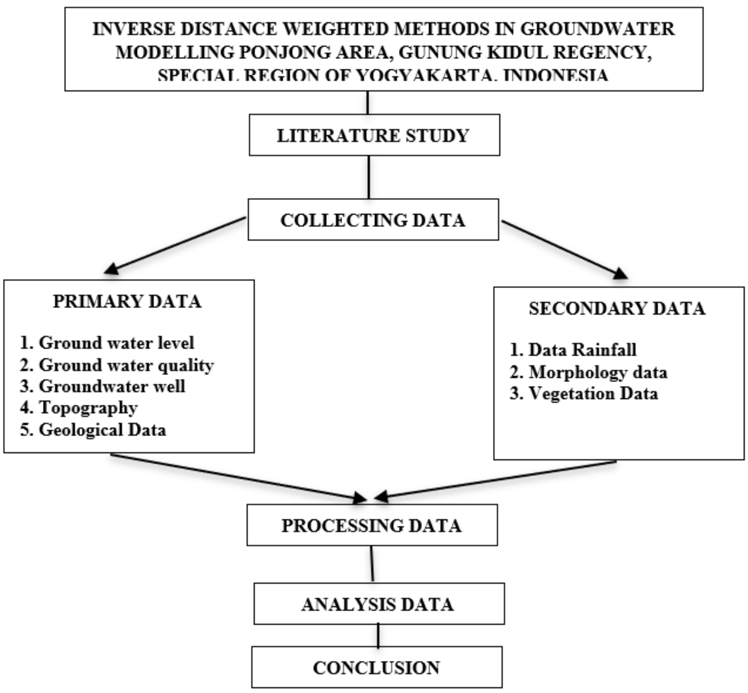
a. Literature Study (primary data collection):

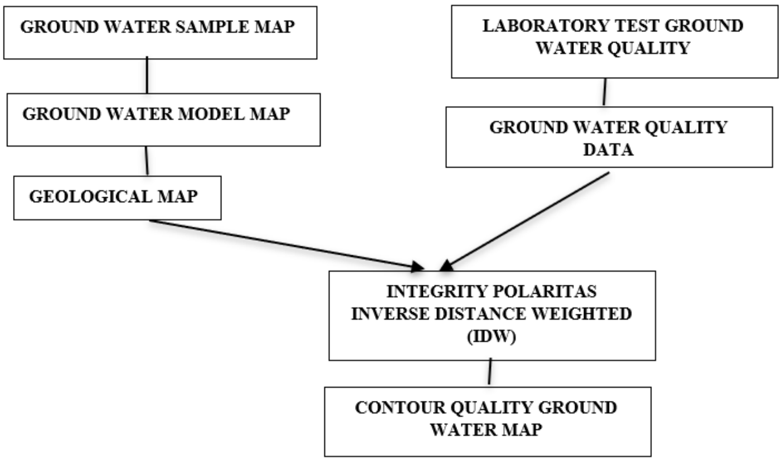
1. Review of the administrative map of Sidorejo Village, Ponjong District, Gunungkidul Regency, Special Region of Yogyakarta.
2. Review of geological and physiographic maps of Sidorejo Village, District Ponjong, Gunungkidul Regency, Special Region of Yogyakarta
3. Prediction existing groundwater models in the area study.
4. Review of central government laws and regulations regional regulations as a comparison of groundwater quality.
5. The results of the literature study produce comparative parameters of quality groundwater.

b. Secondary Data Collection:

Secondary Data
Collection carried out at the research site includes:

1. X, Y, Z coordinates and well conditions at the location water sample.
2. Testing groundwater samples at the Engineering Laboratory
3. General conditions of the research area.





RESULTS AND DISCUSSION

Groundwater Model Analysis

Well Condition

The condition of the well consists of plotting the geographical position of the well, geology, aquifer system, site height, well depth and water table thickness, in which the overall data is obtained by measuring and observing in the field.

a. Geographical position of the well

The geographic position of the well is measured and determined using the Global Positioning System (GPS). So that the X, Y and Z coordinates of each sample well point are obtained.

Table 1. Condition of Sample Wells in Study Area

No.	Sample	East	North	Elevation
1	SM 01	468355	9114414	311
2	SM 02	468418	9114397	307
3	SM 03	468469	9114438	307
4	SM 04	468543	9114392	310
5	SM 05	468330	9114024	312
6	SM 06	468269	9114084	305
7	SM 07	467670	9114182	276
8	SM 08	467425	9113790	285
9	SM 09	469586	9114348	353
10	SM 10	469659	9114273	351
11	SM 11	469339	9114976	346

b. Geology

The geological data of the research location is the data resulting from the interpretation of the geological map. Where is a stratigraphic depiction of the research location. Based on the results of this analysis, the research location is included in the Wonosari formation with geological structures in the form of limestone, reef, calcarenite and calcarenite tuffan.

c. aquifer system

Based on suitability with the study of geological data in the study area, which has a rock structure in the form of limestone, where limestone is a type of rock that has high porosity. So that the research area has the characteristics of a pore aquifer system

d. Well depth

Measurement of the depth of the well is measured by direct measurement using a roll meter with a ballast. The measurement process is carried out by measuring from the bus of the well to the bottom of the well. So that the total depth of each sample well is obtained.

Table 2. Well depth

Sample	SM 01	SM 02	SM 03	SM 04	SM 05	SM 06
Well Depth (Meter)	12	5	14	12	12	12

Tabel 3. Well depth

Sample	SM 07	SM 08	SM 09	SM 10	SM 11
Well Depth (Meter)	11	15	9	11	13

e. The thickness of the groundwater table

Measurement of the thickness of the groundwater table is obtained by subtracting the total depth of the well with the height of the water table. In order to obtain the thickness of groundwater in the sample wells.

Table 4. The condition of the thickness of the groundwater table

Sample	SM 01	SM 02	SM 03	SM 04	SM 05	SM 06
Ground water level (Meter)	10,5	4,5	13,13	10,55	10,65	10,7

Tabel 5. The condition of the thickness of the groundwater table

Sample	SM 07	SM 08	SM 09	SM 10	SM 11
Ground water level (Meter)	10,1	13,85	7,47	9,5	11,5

Groundwater Flow Model

The existing groundwater flow model in the study area tends to move westward, according to the slope of the existing slopes in the study area. However, in the middle part (SM 01, SM 02, BC 03, and SM 04) the groundwater flow direction turns north and south.

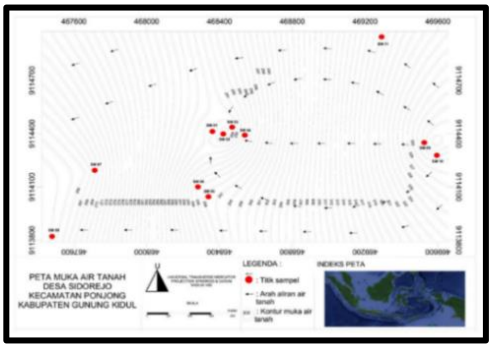


Figure 2. Groundwater Map

Results of Groundwater Quality Assessment Using the IDW Technique

Groundwater quality assessment uses the Inverse Distance Weighting (IDW) technique with physical and chemical content parameters. Physical properties include the degree of acidity (pH), Electrical Conductivity (DHL), Total Disolved Solid (TDS), and chemical properties include the content of Fe, CaCO3, Ca, and Mg.

Quality Assessment Degree of Acidity (pH)

The assessment of the quality of the degree of acidity (pH) using the IDW technique produces a model of the distribution of groundwater pH in the research area.

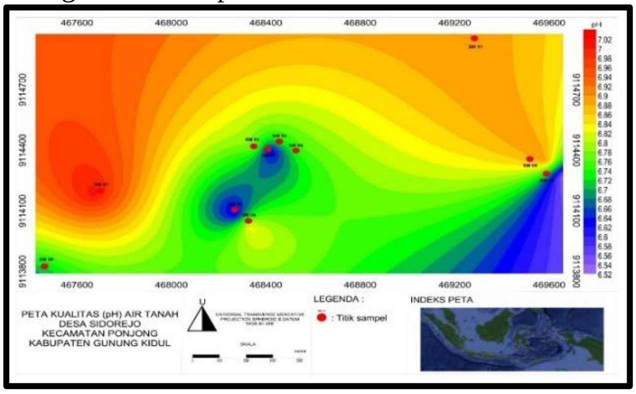


Figure 3. Distribution Map of Groundwater pH

The results of the assessment above show that the distribution of acidity (pH) levels from 6.52 to 6.86 mg/l as indicated by the indigo to orange color spectrum is water quality with a degree of acidity (pH) alkaline, while for levels 6, 88 – 7.02 mg/l which is indicated by a reddish-orange to bright red color spectrum which has a neutral degree of acidity (pH).

Electrical Conductivity (DHL) Assessment

Electrical Conductivity is measured at a standard temperature of 250 C. The conductivity of water depends on the solute per volume. Assessment of the quality of Electrical Conductivity using the IDW technique produces a model of the distribution of Electrical Conductivity of groundwater found at the research area.

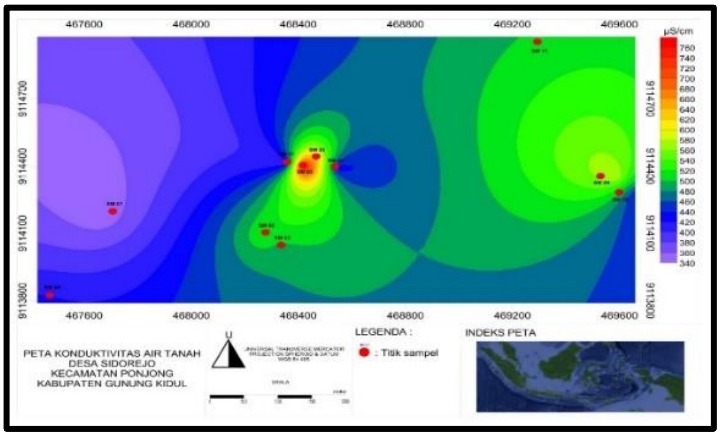


Figure 4. Map of the Distribution of Groundwater Conductivity in the Study Area

The results of the assessment above show that the distribution of Electrical Conductivity levels of 340 – 650 mg/l which is indicated by the indigo to orange color spectrum is the quality of fresh water, while for levels of 660 – 760 mg/l which is indicated by the spectrum reddish-orange to bright red in color with brackish water quality.

Assessment of Total Disolved Solids (TDS)

Assessment of the quality of Total Disolved Solid (TDS) or the amount of dissolved salt using the IDW technique produces a model of the distribution of Total Disolved Solid (TDS) of groundwater found at the research area.

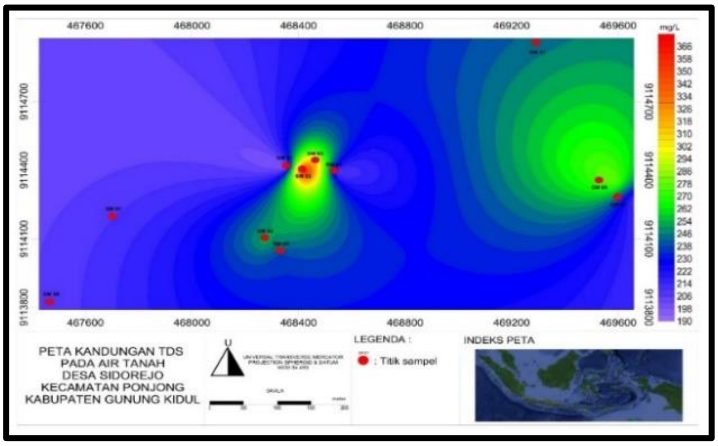


Figure 5. Distribution Map of Groundwater TDS in Study Area

Assessment of Fe content

The assessment of the quality of iron (Fe) using the IDW technique produces a model of the distribution of iron (Fe) in groundwater in the research area.

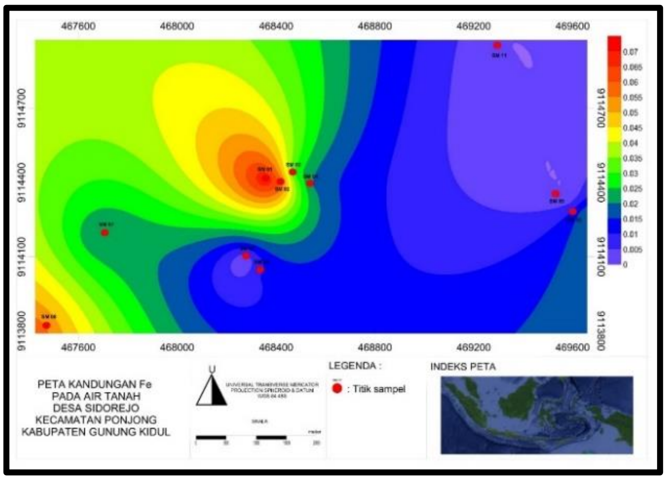


Figure 6. Distribution Map of Groundwater Quality Based on Fe Content

The results of the assessment show that the distribution of iron (Fe) levels from 0 – 0.045 mg/l is indicated by the indigo to yellow color spectrum, while for levels of 0.055 – 0.07 mg/l is shown by the orange to red color spectrum. . The availability of high iron (Fe) content in SM 01 and SM 08 was influenced by several factors including the results of agricultural activities and settlements around the sample points.

Assessment of CaCO3 content

The assessment of the quality of calcium carbonate (CaCO3) using the IDW technique produces a model of the distribution of calcium carbonate (CaCO3) in groundwater in the research area.

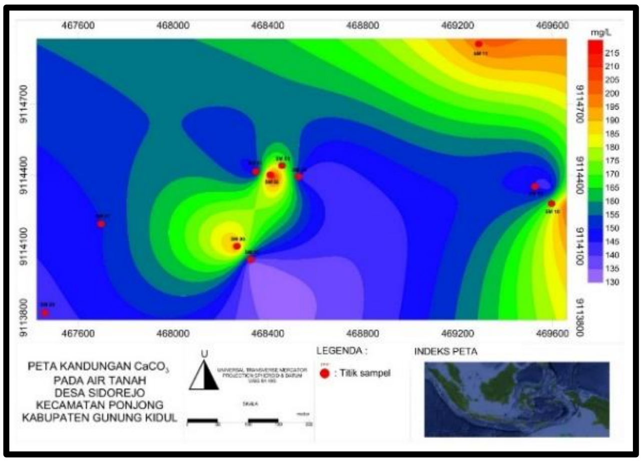


Figure 7. Groundwater Quality Distribution Map Based on CaCO3 Content

The results of the assessment show that the distribution of calcium carbonate (CaCO3) levels of 130 – 185 mg/l is indicated by the indigo to yellow color spectrum, while for levels of 190 – 215 mg/l is shown by the orange to red color spectrum.

Assessment of Ca

The assessment of the quality of calcium (Ca) using the IDW technique produces a model of the distribution of calcium (Ca) in groundwater in the research area.

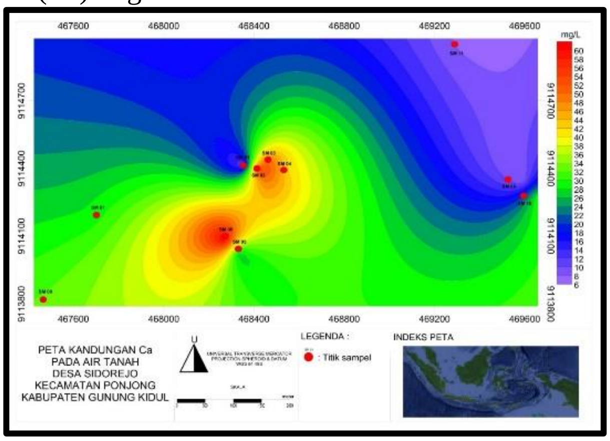


Figure 8. Groundwater Quality Distribution Map Based on Ca Content

The results of the assessment show that the distribution of calcium (Ca) levels from 6 – 40 mg/l is indicated by the indigo to yellow color spectrum, while for levels 42 – 60 mg/l is shown by the orange to red color spectrum.

Assessment of Mg Content

The assessment of the quality of magnesium (Mg) using the IDW technique produces a model of the distribution of magnesium (Mg) in groundwater in the research area.

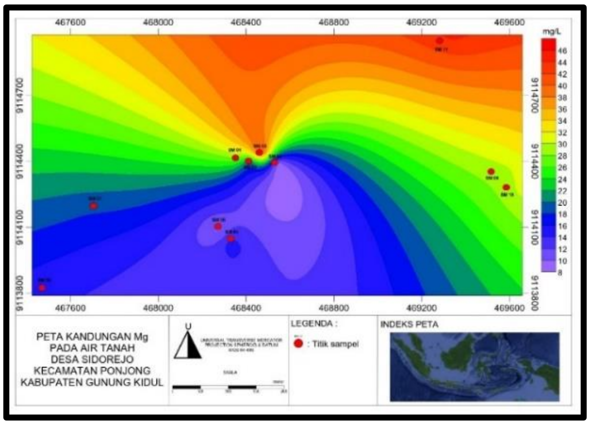


Figure 9. Groundwater Quality Distribution Map Based on Mg Content

The results of the assessment show that the distribution of magnesium (Mg) levels from 8 – 34 mg/l is indicated by the indigo to yellow color spectrum, while for levels 36 – 46 mg/l is shown by the orange to red color spectrum.

CONCLUSION

The groundwater model in Sidorejo Village, Ponjong District, Gunungkidul Regency, Yogyakarta Special Region has a water thickness between 4.5 – 13.85 meters. With a pore aquifer system, because based on data from field observations and interpretation of geological maps, Sidorejo village, Ponjong District, Gunungkidul Regency, Yogyakarta Special Region is included in the Wonosari formation with geological structures in the form of limestone, reef, calcarenite, calcarenite tufan. Meanwhile, the direction of groundwater flow is to the west, following the slope of the study site. From the results of groundwater quality analysis using the Inverse Distance Weighting (IDW) technique by testing several parameters including pH, DHL, TDS, Fe, Ca, Mg, and CaCO3 it can be concluded that all well samples indicated no pollution, because all parameters test is still within normal limits.

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