Available online at: http://proceeding.rsfpress.com/index.php/ess/index
LPPM UPN "Veteran" Yogyakarta Conference Series
Proceeding on Engineering and Science Series (ESS)
Volume 1 Number 1 (2020): 771-783

Hidrogeologi Study of Sand Mine In Merapi Area

Tedy Agung Cahyadi, Rika Ernawati, Genadi Nainggolan, Ilham Firmansyah
Universitas Pembangunan Nasional Veteran Yogyakarta
E-mail address tedyagungc@upnyk.ac.id; E-mail address rika.ernawati@upnyk.ac.id; E-mail address genaditoar@gmail.com; E-mail address ilhamfirmann30@gmail.com

Abstract

Mining activities for sirtu material (sand and stone) have positive and negative impacts. The positive impact is that the extracted material can be used to meet human needs in building infrastructure and infrastructure. The negative impact of gravel mining activities is the occurrence of land-use changes that affect the potential for water absorption and have an impact on the availability of groundwater both quantity and quality. Groundwater vulnerability analysis is carried out as an initial effort in overcoming the decline in groundwater potential, which affects groundwater level groundwater, discharge, surface/land subsidence, and groundwater quality. This research was conducted with sand and stones in Kali Apu, Tlogolele Village. This research was conducted to determine the hydrogeological conditions formed by the mining activity of gravel. Sutui observations were made by assessing several parameters, including the depth of the groundwater level, the amount of recharge, the material for the aquifer media, the material for the soil media, topography, the impact of the unsaturated zone, and the water quality of the research area.

Keywords: vulnerability, groundwater, observation, mining.

I. INTRODUCTION

Water is one of the most important essential of living things. The human need for water is increasing as the population in an area increases. Water is used for primary and secondary needs, on a local to the global scale, and is used for various fields in life (Tjang et al., 2017). The importance of water needs is based on the quantity and quality of water. Based on the quantity, water can be taken from surface water and subsurface water (groundwater) stored in the aquifer layer (Putranto and Kuswoyo, 2008). Groundwater is water is found in the subsoil in saturated water conditions (Todd and Mays, 2005). Groundwater is a water resource that is needed and the most widely used by humans (Hastuti et al., 2016). The advantage of groundwater is that it has a relatively good quality than surface water and is not affected by the season. Groundwater reserves are larger and more comfortable to obtain simply, at a low cost (Sudarmadji and Widyastuti, 2014).

Sand and rock mining activities in Apu River, Tlogolele Village, Selo District can result in changes in land use, morphology, geology, and hydrogeology. These changes can affect topography, subsurface rock layers, and aquifers. (Devy et al., 2014). This land-use change will affect the potential for water absorption, which will have an impact on the availability of groundwater both quantity and quality. A decrease in the potential for groundwater in the mining area is very likely to occur because the floor elevation of the mine opening is far below the ground level, especially the deep groundwater level (Linggasari et al., 2019). The reduction in groundwater potential affects the lowering of the groundwater *level*, groundwater discharge, *surface/land subsidence*, and groundwater quality (Pujianto et al., 2014). Groundwater quality is influenced by the presence or absence of pollutants entering the groundwater and the physical condition of the area. This is because groundwater is found in the soil or rock layers below the soil surface, thus affecting the level of groundwater danger to contamination. The level of groundwater danger is influenced by the level of vulnerability of groundwater itself, and the level of contaminants or pollutants that exist (Haq et al., 2017).

According to Ministerial Decree No.1451 K / 10 / MEM / 2000 regarding technical guidelines for implementing government tasks in the field of groundwater management, groundwater is obliged to be managed and protected from exploitation and pollution. The existence of mining activities can have an impact on the water system and the surrounding environment. The purpose of this study was to determine the hydrogeological condition of the gravel mine, which was formed due to the mining activity of gravel, which supports the analysis of groundwater vulnerability later.

II. LITERATURE REVIEW

Groundwater is closely related to the entry of rainwater into the soil through the infiltration process. Its existence will be significantly influenced by aquifer conditions such as the morphology where the aquifer is located, the type of rock, the type of aquifer formed, and the land cover/use above it (Purnama et al., 2013; Cahyadi, 2017; Riyanto and Widyastuti, 2016; Suprayogi et al., 2016).

According to Piscopo (2001), hydrogeological parameters or factors that affect the potential susceptibility of groundwater contamination are:

Groundwater Depth

This factor is an essential factor because before reaching the groundwater level, contaminants must pass through the thick layer above the groundwater level. The deeper the groundwater level, the smaller the potential for groundwater contamination, and vice versa, the shallower the groundwater level, the greater the potential for groundwater contamination. This is proven by the deeper the groundwater level, the longer the time for contaminants to reach the groundwater level, so the potential for contamination will also be smaller.

Number of *Recharge*

The amount of *recharge* describes the amount of water that seeps into the soil and reaches the groundwater level. Water recharge can assist the transport of contaminants vertically to the groundwater level and horizontally in aquifers. This controls the volume of water containing transported contaminants in the area or saturated or unsaturated water. In general, if the amount of recharge water is more significant, the potential for groundwater contamination will be more tremendous, and vice versa, if the amount of *recharge* water is getting smaller, the potential for groundwater contamination will be smaller.

Aquifer Media

Aquifer media also affects the amount of contaminated surface material, penetrating the aquifer layer. The route by which the contaminants will flow depends on the physical properties of the aquifer media, namely cracks, porosity, or permeability. The greater the ability of aquifers to hold contaminants, the longer the travel time for contaminants to move, so the potential for groundwater contamination will be smaller.

Soil

The soil has a direct and very significant impact from the amount of recharge water that seeps into the soil until it reaches the groundwater level and also affects the movement of contaminants. The ability of soil materials with delicate textures, such as silt and loam, can increase soil permeability and thus limit the movement of contaminants. Soil thickness also affects the travel time of contamination, whether through the process of filtration, biodegradation, absorption, and volatilization significantly. The thicker the travel time will also be longer.

Topography

Topography depends on the slope. Each land surface has a varying slope. Topography helps in controlling contaminants flowing or being held on the surface. Slopes with an enormous potential for contaminants to seep in will be associated with more tremendous potential for groundwater pollution. The steeper the slope, the greater the runoff, so that contaminated water that seeps into the soil and reaches the groundwater level or aquifer layer will also decrease. An area with a gentle slope will cause water to be retained on the surface so that contaminated water will have more potential to infiltrate and pollute groundwater.

Effect of Water Unsaturated Zone

The type of unsaturated water zone is determined based on the characteristics of the material, including the type and boundaries of the soil and rocks below the water table. This material will later become the media. The media will control the direction and length of the path, causing time to decrease, and the quantity of material will also be shorter. The direction of the trajectory is very dependent on the number of cracks that exist, in addition to the influence of soil permeability factors and the depth of the groundwater level.

III. METHOD

The stages in the research conducted by the author are summarized as a flow chart in Figure 1**.** This research is based on the results of direct observations in the field. This research is expected to determine the appropriate method in analyzing the vulnerability of groundwater to mining activity plans.

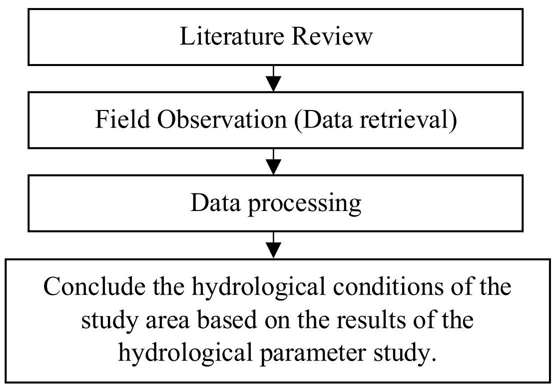

Figure 1: Research Flowchart

IV. RESULTS

Direct observations were made at the research location in order to meet data needs. The research location is dominated by a layer of sand and gravel. This material tends to be homogeneous, causing the results of the research on several parameters such as aquifer media, soil media, and the impact of the unsaturated zone have the same results, namely sand and gravel material. Services online (*web service*) regarding weather data, namely, WWO (*World Weather Online*) and downloaded using Google Colab.

Depth of Ground

Water This spring is located at an elevation of 1269.79 masl. From the observation, it was found that the depth in this research area was very shallow. Shallow groundwater allows more pollutants to enter the aquifer system because it occurs quickly, contaminants will immediately reach the groundwater level, so that areas with such physical conditions have a relatively high vulnerability. Groundwater observation locations can be seen on the Groundwater Surface Location Map (Figure 3).

Figure 2. Observations Front Groundwater

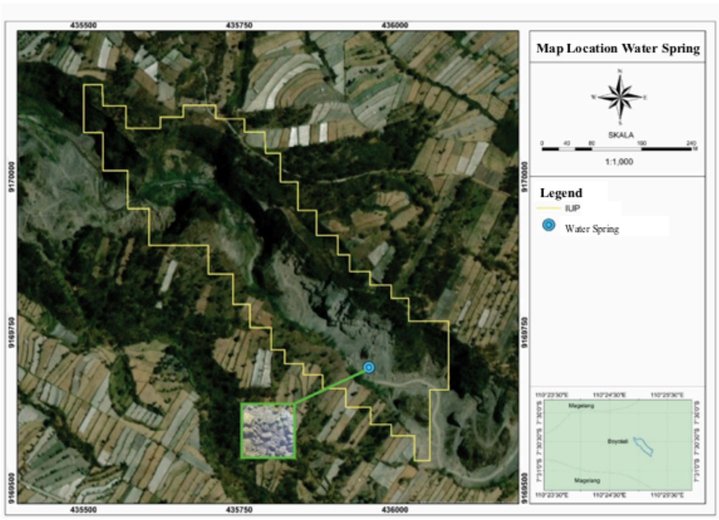

Figure 3. Map Location Water Spring

Amount *Recharge*

The existence of the limited amount of rainfall observation location value, then the value of the study area is homogeneous rain or assumed to be the same throughout the study area. Rainfall in this study was taken from the 2009-2020 rainfall data (Table 1). The amount of monthly rainfall; for 11 years ranges from 173 - 552 mm (Figure 4). Based on the results of data processing, the Rainfall in the study area was included in the high category with an average rainfall value of 2899.65 mm/year, with a maximum rainfall value of 4521.8 mm/year. This is supported by data from the Boyolali Regency Regional Profile document, namely the Boyolali Regency rainfall map (Figure 5). Based on this map, the Rainfall in Selo District is classified as high with a rainfall intensity of <2000 mm / year. This shows that in terms of groundwater (*recharge*), the research area has relatively high groundwater vulnerability or high potential for contamination.

Table 1 Data Rainfall Year 2009-2020

Year	Monthly Rainfall (mm)												Total (mm/Year)	Rata-rata Monthly (mm/month)
	January	February	March	April	Mei	June	July	August	September	October	November	December		
2009	242.40	242.30	191.30	277.60	219.30	111.10	74.10	42.70	93.80	186.30	227.10	170.40	2078.40	173.20
2010	197.90	361.80	290.50	206.70	368.70	253.40	229.70	232.80	370.80	377.10	376.10	136.60	3402.10	283.51
2011	102.90	127.60	179.90	293.30	307.00	104.50	134.80	30.10	55.10	258.30	389.30	164.30	2147.10	178.93
2012	187.40	223.90	99.90	309.60	242.10	117.30	55.60	22.60	52.30	185.20	389.10	291.70	2176.70	181.39
2013	180.20	260.50	275.70	331.50	310.90	234.80	214.30	77.30	44.30	160.10	193.00	163.80	2446.40	203.87
2014	147.20	143.80	293.60	256.40	329.50	264.80	164.40	67.50	52.00	141.40	368.60	184.00	2413.20	201.10
2015	159.50	236.20	395.60	345.70	101.50	98.40	11.30	10.00	49.00	55.70	474.40	407.80	2345.10	195.43
2016	387.70	369.70	470.20	385.20	402.40	238.60	127.60	138.10	278.00	372.90	546.60	163.70	3880.70	323.39
2017	226.70	373.70	242.10	415.10	230.10	146.40	55.30	27.70	110.90	239.60	429.90	248.20	2745.70	228.81
2018	336.50	253.70	322.70	273.90	175.40	109.30	19.70	18.40	85.90	77.70	292.00	254.30	2219.50	184.96
2019	698.80	790.30	850.30	687.30	203.70	44.80	33.40	8.40	14.40	67.70	223.40	899.30	4521.80	376.82
2020	665.80	732.10	1117.40	766.10	654.50	194.80	125.20	163.20	-	-	-	-	4419.10	552.39
CH Monthly	294.42	342.97	394.10	379.03	295.43	159.85	103.78	69.90	109.68	192.91	355.41	280.37		
CH Max	698.80	790.30	1117.40	766.10	654.50	264.80	229.70	232.80	370.80	377.10	546.60	899.30		
CH Min	102.90	127.60	99.90	206.70	101.50	44.80	11.30	8.40	14.40	55.70	193.00	136.60		
Average Annual Rainfall (mm/Year)														2899.65
Maximum Average Annual Rainfall (mm/Year)														4521.80
Minimum Average Annual Rainfall (mm/Year)														2078.40

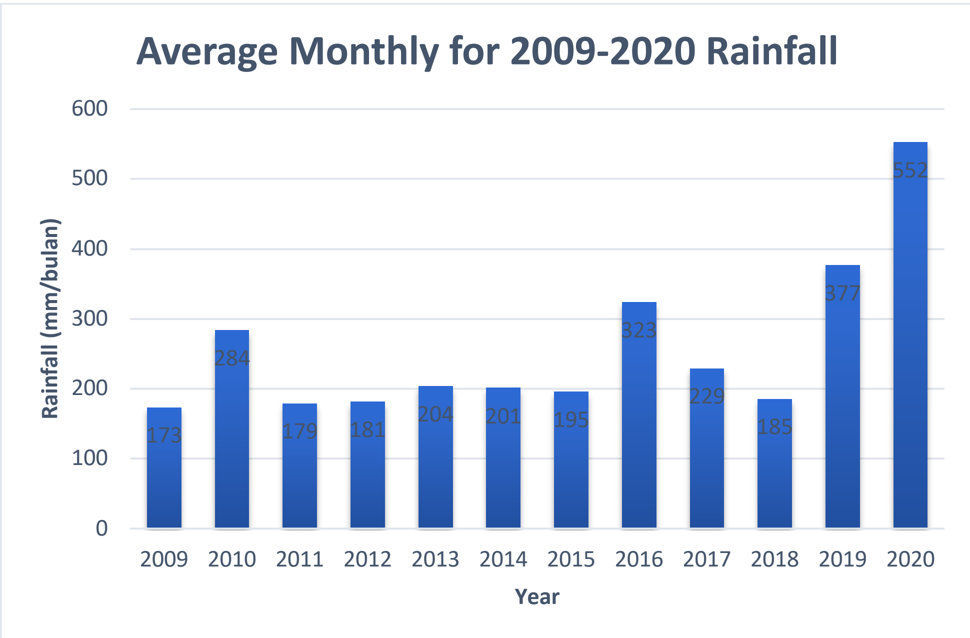

Figure 4. Graph of Average Monthly for 2009-2020 Rainfall

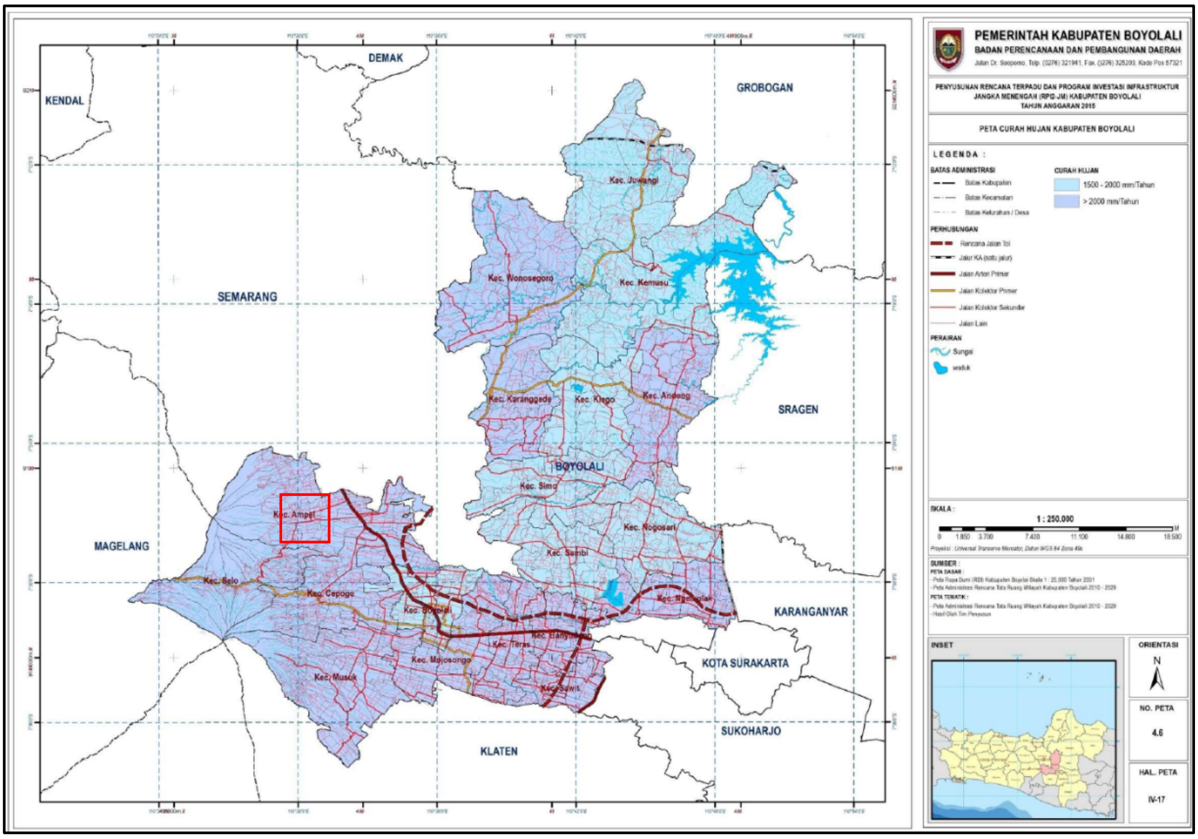

Figure 5. Rainfall Map of Boyolali Regency

Aquifer Media

In general, the research area is dominated by sand and gravel. Several layers that are easily traversed by groundwater and act as an aquifer medium, are sand and gravel layers (Figure 6). This shows that the research area has a reasonably high vulnerability condition.

Figure 6. Sand and Gravel Aquifer

Media Soil

The soil has a direct impact on the amount of water that infiltrates the soil until it reaches the groundwater table and affects the movement of contaminants. The ability of soil materials with coarse textures, such as sand, can increase soil permeability, limiting the movement of contaminants less. Based on field observations, the soil texture in the study area is dominated by sand (Figure 7). This shows that the research area has a high vulnerability condition.

Figure 7. Sand Soil Media

Topography

The slope parameter is obtained from the contour of the topographic map of the study area (Figure 8). The results of topographic measurements vary from a slope of 6% to 80%. The research area is dominated by a slope of> 18% with a rating of 1. This indicates that the groundwater vulnerability of the topographic media parameters is very low. The weighted classification of the topographic slope of the study area can be seen in Table 2. The results of the classification of the slope of the study area can be seen in Figure 9.

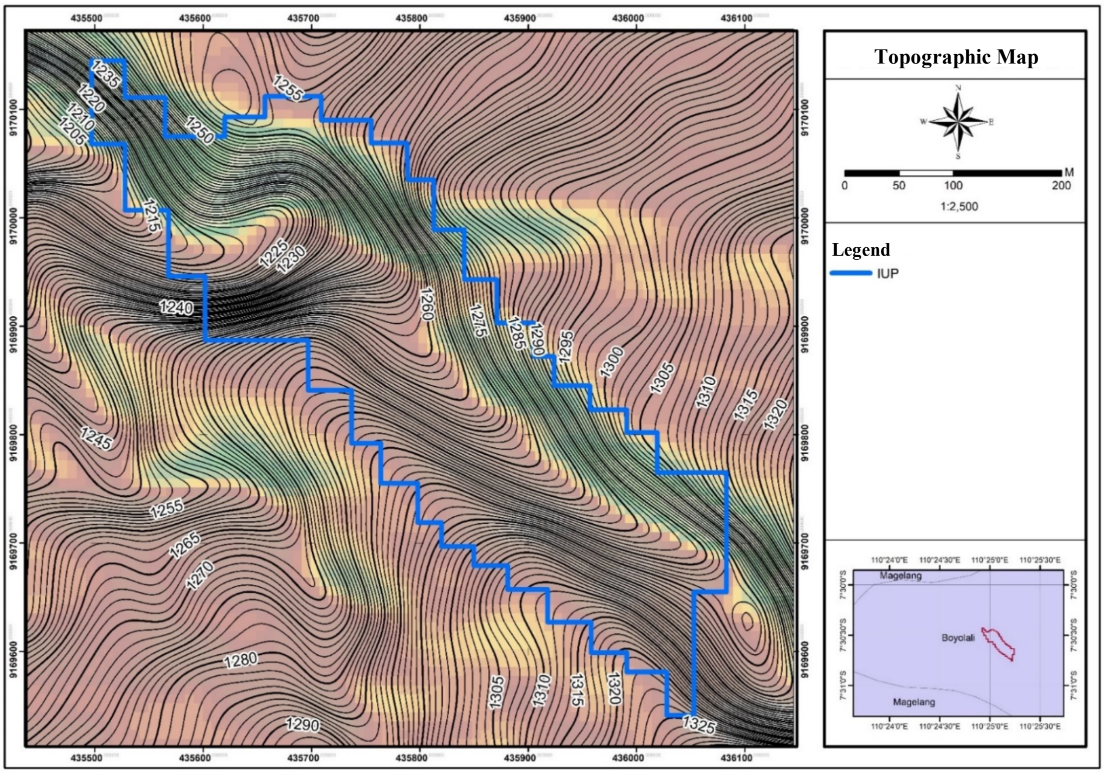

Figure 8. Topographic Map

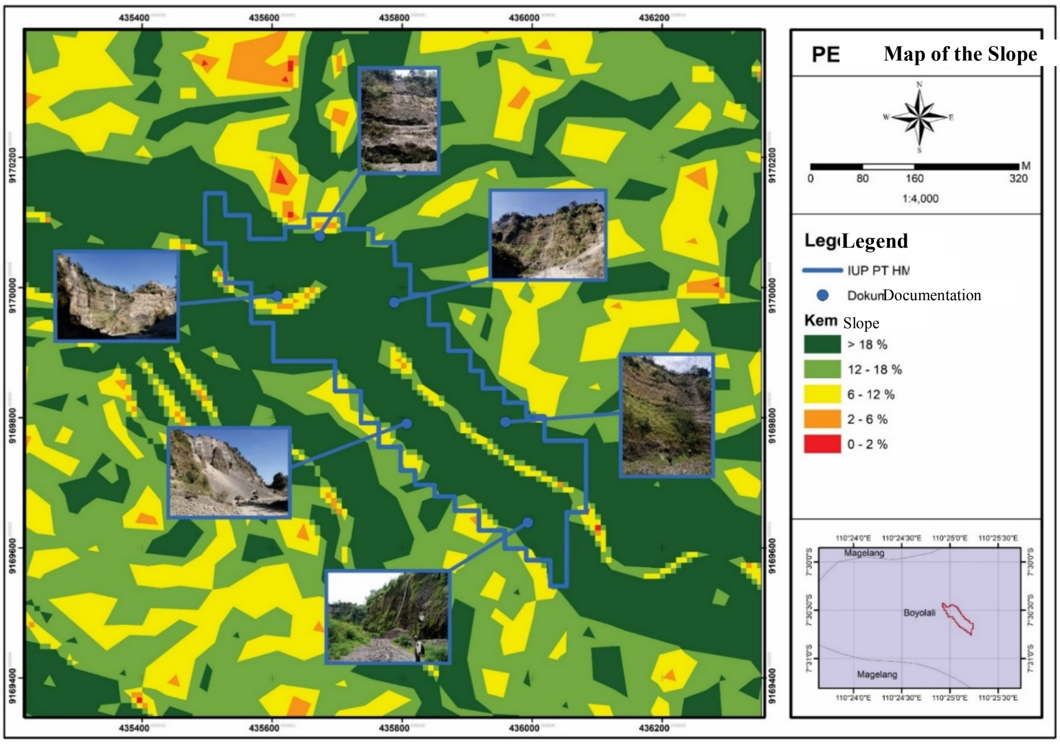

Figure 9. Map of the Slope

Impact of the Unsaturated

Zone The unsaturated zone is a parameter that classifies the types of material that exist. In the zone between the ground surface and the water level. This material will control the direction and time it takes for contaminants to reach groundwater. The identification of the unsaturated zone material in the study area obtained sand and gravel (Figure 10). This shows that the research area has a reasonably high susceptibility condition.

Figure 10. Sand and Gravel Layer as Unsaturated Zone

Water Quality

Water quality measurements were carried out on water samples taken from watercourses and compartments located at the study site. The location of water samples can be seen on the map of water sample locations (Figure 12). Field measurements of groundwater include measurements of pH, total dissolved solids, or *Total Dissolved Solids* (TDS), temperature, and *electric conductivity* (DHL). The tools used in this measurement are the pH meter and the TDS-EC meter (Figure 11). The results of the measurement of the physical properties of groundwater can be seen in Table 3.

Figure 11. pH Meter and TDS-EC Meter

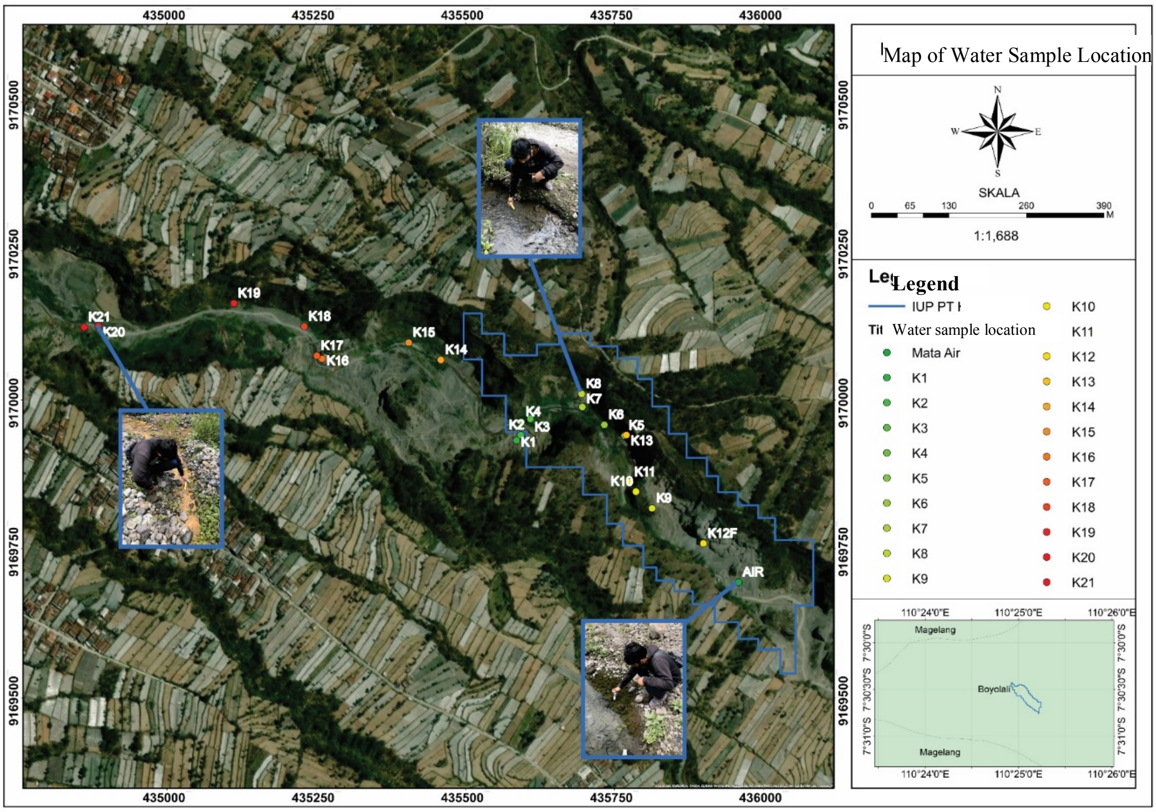

Figure 12. Map of Water Sample Location

Table 3. Groundwater Quality Test Results

Sample	Location			Parameters			
	x	y	z	pH	EC (μs/cm)	TDS (ppm)	Temperature (˚C)
Water Springs	435958	9169694	1270	7.2	193	96	24.2
K1	435586	9169932	1208	8.5	190	95	24.8
K2	435593	9169941	1208	7.5	186	93	24.6
K3	435609	9169968	1260	7.4	186	93	24.3
K4	435594	9169963	1263	8.3	184	92	23.3
K5	435767	9169940	1288	7.8	195	97	23.8
K6	435733	9169958	1282	7.6	193	83	24
K7	435696	9169988	1277	7.8	196	98	23.7
K8	435695	9170010	1273	8.0	192	96	22.6
K9	435813	9169818	1273	7.7	201	100	25
K10	435786	9169846	1269	7.5	195	97	25
K11	435776	9169862	1272	7.5	195	97	24
K12	435899	9169759	1280	7.6	209	104	25.7
K13	435770	9169941	1300	7.7	193	96	26
K14	435459	9170067	1193	7.3	211	105	24.5

K15	435405	9170096	1186	7.3	213	106	24.8
K16	435260	9170069	1175	7.3	190	95	24.7
K17	435251	9170074	1172	7.5	200	100	24.3
K18	435230	9170123	1167	7.3	199	99	24.8
K19	435112	9170162	1157	7.9	199	99	24.8
K20	434885	9170124	1141	6.7	365	182	24.3
K21	434861	9170122	1137	7.1	212	99	25.5

V. DISCUSSION

Results of the assessment of the parameters for the depth of the groundwater level, the amount of *recharge*, the materials that make up the media aquifers, the building blocks of soil media, and the impact of the unsaturated zone show that the research location has poor hydrogeological conditions and is prone to pollution. However, in fact, the results of direct water quality tests in the field with pH, EC, TDS, and temperature parameters show that the water quality at the research location is still good despite ongoing mining activities in the vicinity.

Recommendation

The location where mining activities occur needs to be moved and given a certain distance that is quite far from the spring. Refuelling and vehicle oil change activities should not be carried out near springs. This is done as a preventive measure to increase the potential for water pollution.

VI. CONCLUSION

Based on field observational studies regarding hydrogeological conditions in the sirtu mine, it can be concluded:

a. The results of the assessment of the parameters for the depth of the groundwater level, the amount of *recharge*, the material that makes up the aquifer media, the material that makes up the soil media, the impact of the unsaturated zone shows that the research location has poor hydrogeological conditions vulnerable to contamination.
b. The results of water quality tests in the field indicate that the current water quality is good.

ACKNOWLEDGMENTS

In preparing this paper, the support from various parties, especially to the Mining Engineering Study Program of UPN "Veteran" Yogyakarta, was inseparable and LPPM UPN “Veteran” Yogyakarta as provide research funding.

REFERENCES

Haq, S. R., Dwinagara, B., & Cahyadi, T. A. (2017). Analisis Tingkat Kerentanan Airtanah Pada Rencana Pertambangan Batubara Di Barito Timur, Kalimantan Tengah (in Indonesia language).

Hastuti, D., Yulianto, T., dan Putranto, T.T. 2016. Analisis Kerentanan Airtanah terhadap Pencemaran di Dataran Alluvial Kota Semarang Menggunakan Metode GOD dengan

Memanfaatkan Data Resistivitas dan Data Hidrogeologi. *Youngster Physics Journal*, 5(4): 277–290 (in Indonesia language).

Linggasari, S., Cahyadi, T. A., & Ernawati, R. (2019). Overview Metode Perhitungan Kerentanan Airtanah Terhadap Rencana Penambangan. *ReTII*, 123-129 (in Indonesia language).

Piscopo, Gennaro. 2001. Groundwater Vulnerability Map Explanatory Notes. *NSW Department of Land and Water Conservation.*

Pujianto, E., Supangkal, H., Utomo, N. M., & Hakim, A. (2011). Studi Pengaruh Penambangan Batubara Terhadap Kondisi Potensi Air Tanah di Daerah Kalimantan Selatan. *Puslitbang Teknologi Mineral dan Batubara* (in Indonesia language).

Todd, D.K. dan Mays, L.W. 2005. *Ground Water Hydrology*. New York: John Willey and Sons, Inc.

TT, P. T. P., & Kuswoyo, B. Zona Kerentanan Airtanah terhadap Kontaminan dengan Metode Drastic. *Teknik*, *29*(2), 110-119 (in Indonesia language).

Sudarmadji, Hadi P., dan Widyastuti. M. 2014. Pengelolaan Sumberdaya Air Terpadu. *Gadjah Mada University Press*. Yogyakarta (in Indonesia language).

Suprayogi, S.; Purnama, S.; Agniy, R.F. dan Cahyadi, A. 2016. Potensi Airtanah Statis di daerah Tangkapan Air Goa Pindul Kabupaten Gunungkidul. *Prosiding Seminar Nasional Geografi Lingkungan*. Yogyakarta: Fakultas Geografi Universitas Gadjah Mada (in Indonesia language).

Tjang, Andreas Archie Candra Saputra Wijaya., Thomas Triadi Putranto., Istiqomah Ari Kusuma. 2017. Studi Kerentanan Air Tanah Terhadap Pencemaran dan Pemompaan Dengan Metode Groundwater Occurance, Overlying Lithology, dan Depth of Groundater (GOD) di Kecamatan Grobogan dan Kecamatan Purwodadi, Kabupaten Grobogan, Provinsi Jawa Tengah. *Tesis.* Universitas Diponegoro (in Indonesia language).