Gmail

listyani theo <listyanitheophila@gmail.com>

Submission Lis-1

listyani theo <listyanitheophila@gmail.com> 10 Desember 2019 22.13
Kepada: geologicalsociety@gmail.com

Dear Editor of Geological Society of Malaysia
c/o Department of Geology, University of Malaya
50603 Kuala Lumpur, MALAYSIA

Attached is our article for Bulletin of the Geological Society of Malaysia.
We hope that you will be pleased to accept our manuscript. We're waiting for your review and reply as soon as possible.
Thank you.

Best Regards.
Lis
ITNY, Yogyakarta, Indonesia

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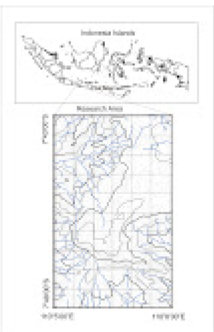

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2. Lis_All Fig & Table.docx
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Submission Lis-1

Geological Society of Malaysia <geologicalsociety@gmail.com> 16 Desember 2019 14.01
Kepada: listyani theo <listyanitheophila@gmail.com>

Thank you for your valuable contribution, Listyani.

We need a favour. Please rephrase the title of your paper. Please rewrite the abstract so that both will be different from the extended abstract which you submitted for NGC2019. This was the advise given by the ISI-indexing committee.

Please send your revised manuscript by a **FRESH EMAIL**.

The number of words should be more than 3,000 words. It should be in word format. No need to format the paper. The guideline is attached for your reference.

Regards. Have a good day.

Anna
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Guideline for GSM publications.pdf
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Geological Society of Malaysia Publications

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Only papers that have not been published elsewhere will be considered for publication. Authors must agree not to publish elsewhere a paper submitted and accepted. All papers will be subjected to review by two or more reviewers. Authors wishing to include published and unmodified figures or text passages are required to obtain permission from the copyright owner(s). Authors of English papers are strongly urged to have their manuscript edited for language before submission by a person whose first language is English.

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Manuscript

The paper can be written in Bahasa Malaysia (Malay) or English. For English papers, use either British or American spelling but not a combination of both. The paper should be checked thoroughly for spelling and grammar. The manuscript must be printed at 1.5 spacing in a single column on one side of A4 paper. All pages should be numbered. Length of paper should be between 3,000 and 6,000 words for the *Bulletin* and between 2,000 and 3000 words for *Warta Geologi*, excluding tables and illustrations. Metric units should be used and all non-standard symbols, abbreviations and acronyms must be defined.

Title

Title must be informative and reflects the content of the paper. Title in Malay should include an English translation. It should be concise (less than 20 words). Avoid using abbreviation in the title.

Author's Address

Addresses of all authors must be provided. The addresses should be sufficient for correspondence. Please include email address, telephone and fax of the corresponding author.

Abstract

Abstract in both Malay and English, each in one paragraph and should not exceed 300 words. It should clearly identify the subject matter, results obtained, interpretations discussed and conclusions reached.

Keywords

Please include 3 to 8 keywords that best describe the content of the paper.

References

In the text, references should be cited by author and year and listed chronologically (e.g. Smith, 1964; Jones *et al.*, 1998; Smith & Tan, 2000). For both Malay and English paper, all references must be listed in English. Title of non-English articles should be translated to English.

The list of references should only include articles cited in the text. The list should be arranged in alphabetical order. Please ensure that the reference list is complete and the bibliographical details are accurate. The references should be in the following manner:

Journal article:

Suntharalingam, T., 1968. Upper Palaeozoic stratigraphy of the area west of Kampar, Perak. Geol. Soc. Malaysia Bull., 1, 1-15.

Book:

Hutchison, C.S., 1989. Geological Evolution of South-east Asia. Clarendon Press, Oxford. 368 p.

Chapter of book and Symposium volume:

Hosking, K.F.G., 1973. Primary mineral deposits. In: Gobbett, D.J. and Hutchison, C.S. (Eds.), Geology of the Malay Peninsular (West Malaysia and Singapore). Wiley-Interscience, New York, 335-390.

Article in Malay:

Lim, C.H. & Mohd. Shafeea Leman, 1994. The occurrence of Lambir Formation in Ulu Bok Syncline, North Sarawak. Geol. Soc. Malaysia Bull., 35, 1-5. (in Malay with English abstract).

Tables

All tables should be cited in the text and numbered consecutively. Tables should have a title and a legend explaining any abbreviation or symbol used. Each table must be printed on a separate piece of paper. Do not insert the tables within the text. Data in tables should be aligned using tab stops rather than spaces. Avoid excessive tabulation of data.

Illustrations

Please make sure that all illustrations are useful, necessary and of good quality. A maximum of ten (10) illustrations (photographs, graphs and diagrams) are allowed and these should be cited in the text and numbered consecutively as Figures. The papers are usually published in black-and-white but it may sometimes be possible to include colour figures at the author's expense. The scales for maps and photomicrographs should be drawn on the figure and not given as a magnification. Originals should not be greater than A4 size and annotations should be capable of being reduced down to 50 percent. The caption should be listed on a separate piece of paper. Do not insert the illustration within the text.

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Submission should be made through email as attachment files or using CD-ROM. The submission should be accompanied with a listing of all files and the software (name and version) used. The file names should reflect the content of the files (e.g. Ali_Fig1.tif).

Preferred Software

Text: Microsoft Word. Do not insert tables and illustration within the text.

Tables: Microsoft Word or Microsoft Excel. Please submit as separate files.

Illustrations – Vector Graphics: Adobe Illustrator (preferred), CorelDraw and Freehand. Final line thickness should be at least 0.5 point or 0.17 mm. For other software, please submit one copy in the native file format and export one copy as a PDF file with all fonts embedded and one copy as a high resolution TIFF or JPEG image.

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Gmail **listyani theo <listyanitheophila@gmail.com>**

Submission Lis-3

listyani theo <listyanitheophila@gmail.com> 10 Desember 2019 22.19
Kepada: geologicalsociety@gmail.com

Dear editor
Attached are our illustrations again
Thank you

Lis
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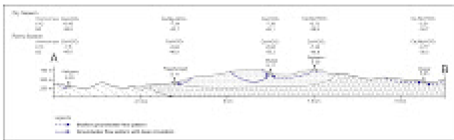

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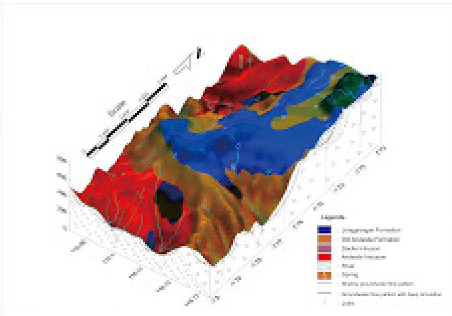

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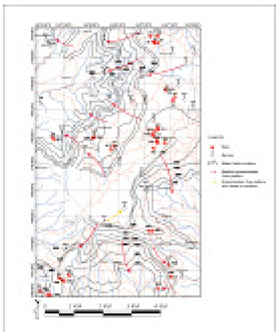

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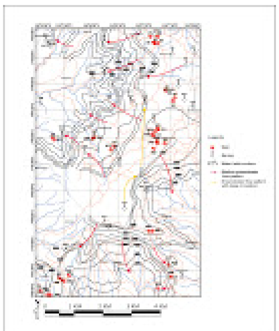

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listyani theo <listyanitheophila@gmail.com>

Submission Lis-3

Geological Society of Malaysia <geologicalsociety@gmail.com> 16 Desember 2019 14.02
Kepada: listyani theo <listyanitheophila@gmail.com>

Please compile your plates in 1 file, Listyani.

The same for your figures and tables. It will be easier to send for review.

Thank you for your cooperation.
[Kutipan teks disembunyikan]

Gmail **listyani theo <listyanitheophila@gmail.com>**

Acknowledgement of receipt of manuscript

Wan Aida <aidaawann@gmail.com> 26 Januari 2020 07.00
Kepada: listyanitheophila@gmail.com, Geological Society of Malaysia <geologicalsociety@gmail.com>

Dear Ms Listyani,
Thank you for submitting your manuscript *"Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics"*
to the Bulletin of the Geological Society of Malaysia. The Letter of Acknowledgement of Receipt is hereby enclosed.

Thank you.

Yours sincerely,
Wan Aida
on behalf of the Geological Society of Malaysia

1- acknowledgement letter.doc
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Gmail **listyani theo <listyanitheophila@gmail.com>**

Acknowledgement of receipt of manuscript

listyani theo <listyanitheophila@gmail.com> 25 April 2020 14.12
Kepada: Wan Aida <aidaawann@gmail.com>

Dear Editor

I have submitted my manuscript, titled **Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics** on 6th December 2019 (Reference no.: 6.12.2019).

May I have an enquiry on the status of my manuscript?

Thank you.
Best regards

T. Listyani R.A.
Department of Geological Engineering,
Institut Teknologi Nasional Yogyakarta,
Babarsari, Yogyakarta,
55281, Indonesia
[Kutipan teks disembunyikan]

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listyani theo <listyanitheophila@gmail.com>

Acknowledgement of receipt of manuscript

Wan Aida <aidaawann@gmail.com> 27 April 2020 14.14
Kepada: listyani theo <listyanitheophila@gmail.com>

Dear Ms Listyani,
With regard to your manuscript status, we are sorry to inform you that there is a delay in the paper reviewing process. This is because one of the two earlier reviewers had not been able to complete the review after the arranged period, and thus it has to be sent to another reviewer.
We apologize for the delay. The manuscript will be sent back to you for updating once the review has been completed.
Thank you for your understanding.

Sincerely,
Wan Aida

Gmail

listyani theo <listyanitheophila@gmail.com>

Manuscript Submitted to The Geological Society Of Malaysia

Wan Aida <aidaawann@gmail.com> 29 Mei 2020 09.20
Kepada: listyani theo <listyanitheophila@gmail.com>, Geological Society of Malaysia <geologicalsociety@gmail.com>

Dear Ms Listyani,
I am writing regarding your manuscript entitled **Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics**, submitted on 6 December 2019.
The Editorial Committee has invited numerous potential reviewers to review it, but only one has agreed to review it.
The review process should be completed soon.
Therefore, as we require a minimum of two reviewers to review every submission, please suggest a few persons who are suitable to review your manuscript for our further action.
Thank you.

Yours sincerely,
Wan Aida
GSM Editorial Committee

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listyani theo <listyanitheophila@gmail.com>

Manuscript Submitted to The Geological Society Of Malaysia

listyani theo <listyanitheophila@gmail.com> 29 Mei 2020 12.06
Kepada: Wan Aida <aidaawann@gmail.com>

Dear editor,
Here are suggested reviewers for my manuscript:

1. Name: Dr. Ir. Vijaya Isnaniawardhani
   Email: vijaya_djatmiko@yahoo.com;
   vijaya.isnania@unpad.ac.id

2. Name: Dr. Agus Didit Haryanto
   Email: agus.didit.haryanto@unpad.ac.id

3. Name: Dr. Thomas Triadi Putranto
   Email: putranto@ft.undip.ac.id

Thank you
Best regard,
Lis, Indonesia

[Kutipan teks disembunyikan]

Gmail **listyani theo <listyanitheophila@gmail.com>**

Status of Manuscript Submitted To The Geological Society Of Malaysia

Wan Aida <aidaawann@gmail.com> 5 Agustus 2020 22.06
Kepada: listyani theo <listyanitheophila@gmail.com>, Geological Society of Malaysia <geologicalsociety@gmail.com>

Dear Ms Listyani,

We are pleased to inform you that the review of your manuscript entitled **Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics** has been completed.

Enclosed please find a zip folder containing the marked manuscript and the filled evaluation forms for your further action.

Thank you. We look forward to receiving the revised manuscript from you soon.

Yours sincerely,
Wan Aida
for the Editor, BGSM

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MS for correction letter.docx
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Comments for author.zip
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listyani theo <listyanitheophila@gmail.com>

Status of Manuscript Submitted To The Geological Society Of Malaysia

listyani theo <listyanitheophila@gmail.com> 21 Agustus 2020 18.27
Kepada: Wan Aida <aidaawann@gmail.com>

Dear editor
Attached are my revision files.
We look forward to good news from you soon.
Thank you very much

Best regards,
Lis,
ITNY Indonesia

Pada tanggal Rab, 5 Agu 2020 pukul 22.10 Wan Aida <aidaawann@gmail.com> menulis:
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Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics

Abstract: Groundwater studies were carried out in the center of the West Progo Dome with an emphasis on hydrochemical problems. As a water-scarce area, groundwater studies are urgently needed in this area. This research is intended as a hydrogeological study with the aim of knowing the conceptual groundwater flow model in the study area. The method used is a field hydrogeological survey as well as hydrochemical and natural isotope analysis supported by chemical and groundwater isotope data. Less clear hydrochemical evolution indicates that the process of groundwater flow is dominant in the local flow system. Groundwater facies is dominated by bicarbonate type, neutral pH, relatively low TDS, and EC, and influenced by season or rainfall. The dominant hydrochemical processes in the groundwater system are leaching, ion exchange, sulfate reduction, and dilution. Groundwater facies is determined by the rock minerals marked by differences in hardness and TDS. Whereas, stable isotope contents of groundwater vary from light to heavy. Springs with light isotopes show the circulation of deep groundwater flow or from a relatively high recharge zone, either locally or from other places around it. Isotopic enrichment in all seasons can occur due to evaporation or mixing with surface water that has undergone previous evapotranspiration, indicated by increasing of heavy isotopes or δD-excess (d) of groundwater. There are two types of groundwater flow patterns, namely shallow and deep groundwater flow patterns. Shallow groundwater is characterized by heavy isotopes, shifted with relatively small d. Deep groundwater circulation pattern is characterized by a consistent, light δD value and appreciable d.

Keywords: groundwater; flow system; pattern; hydrochemistry; stable isotopes.

Abstrak: Corak aliran air bawah tanah telah dipelajari di pusat Kubah Kulon Progo oleh analisis hidrokimia dan isotop. Sebagai kawasan yang kekurangan air, kajian air bawah tanah diperlukan di daerah ini. Penyelidikan ini bertujuan sebagai kajian hidrogeologi dengan tujuan mengetahui model aliran air bawah tanah secara konseptual di kawasan kajian. Kaedah yang digunakan adalah tinjauan hidrogeologi lapangan serta analisis isotop hidrokimia dan semula jadi yang disokong oleh data kimia dan sampel isotop air bawah tanah. Evolusi hidrokimia tidak jelas menunjukkan proses aliran air tanah berada dalam sistem aliran tempatan. Fisi air bawah tanah dikuasai oleh jenis bikarbonat, pH neutral, TDS dan EC yang rendah dan dipengaruhi oleh musim atau hujan. Proses hidrokimia dominan adalah larutan, pertukaran ion, pengurangan sulfat, dan pencairan. Air bawah tanah mengalir dalam akuifer Jonggrangan dan Old Andesite. Jenisnya ditentukan oleh mineral-mineral batu yang ditandakan dengan perbezaan kekerasan dan TDS. Sementara itu, kandungan isotop yang stabil air bawah tanah berbeza dari ringan ke berat. Mata air dengan isotop ringan menunjukkan peredaran aliran air bawah tanah atau dari zon penyerapan semula yang tinggi, sama ada dari dalam atau dari tempat lain di sekelilingnya. Pengayaan isotop pada semua musim boleh berlaku disebabkan oleh penyejatan atau pencampuran dengan air permukaan yang telah mengalami evapotranspirasi terdahulu, ditunjukkan oleh peningkatan isotop berat atau δD-berlebihan (d) air bawah tanah. Terdapat dua jenis corak aliran air bawah tanah, iaitu corak aliran air bawah tanah yang cetek dan mendalam. Air bawah tanah cetek dicirikan oleh isotop berat, beralih, dengan d relatif kecil. Corak peredaran air bawah tanah mendalam dicirikan oleh nilai δD yang konsisten, ringan dan d air bawah tanah yang cukup besar.

Kata kunci: air bawah tanah; sistem aliran; corak; hidrokimia; isotop stabil

INTRODUCTION

The study area is well known as hard water area (Listyani *et al*, 2018). Landform in theis area shows high elevation of steeply hills, with wet tropical climate. The weather shows that the air temperature generally ranges from 22°C – 32°C, with an average temperature of 26°C. The evaporation seems moderate in rainy season and increases when dry season. Rainfall rates is in high range (300 – 400 mm/month) in rainy season and moderate (100 – 150 mm/month) in dry season (Meteorology Climatology and Geophysics Council, 2018), or 3000 – 4000 mm/year (Putranto & Aryanto, 2018).

The problem of water resources is often an important thing that must be considered today. Various surface and groundwater problems are examined to obtain sufficient and good quality water resources. Surface water that is too much-flooded needs to be addressed (Mera & Rantoso, 2019), but the presence of too little groundwater is also a serious problem. West Progo Hill is an area that often suffers from water shortages, therefore water resources investigations need to be carried out in this area. As hard water area, this region consists of colluvium and fractured rock aquifers. Thus, a study on groundwater potential is important in this area.

Groundwater studies have developed rapidly along with the need for groundwater in various regions. This study is important to be carried out in order to understand water resources through various studies. This paper is the result of hydrogeological mapping activities with the aim of understanding the system and pattern of groundwater flow in the West Progo area, especially in the central part. The results achieved are groundwater flow models that are known based on hydrochemical and stable isotopes of ^{2}H (deuterium, D) and oxygen-18 (^{18}O) characteristics. Isotope analysis has been widely developed in hydrogeological studies in many places. Hydroisotope method using ^{2}H and ^{18}O has been chosen because of its relatively low cost of analysis (Irawan, 2009; Alam et al, 2014). The advantage of using the stable isotopes $\delta^{18}O$ and $\delta^{2}H$ compared to other isotopes is that the content of these stable isotopes in rainwater shows a linear relationship in the form of a global meteoric water line (Satrio & Sidauruk, 2015).

Although the research area is a hard water region (Listyani *et al*, 2018, 2019), groundwater hydrochemical analysis can assist to determine groundwater flow systems. This analysis can be done by determining the groundwater chemical facies/types. Aquifer hydrogeochemical characteristics are also determined to identify groundwater flow patterns and the interpretation of hydrochemical processes. Isotope analysis is useful to help interpret groundwater flow patterns. The results of groundwater hydrochemical analysis can be verified by isotope analysis so as to produce a better interpretation of the groundwater flow system.

Many researchers have conducted groundwater research using hydrochemical methods in an area, including by utilizing groundwater chemical composition to determine their behavior in aquifers (Alam *et al*, 2014, 2019; Putranto *et al*, 2017; Putranto and Aryanto, 2018; Setiawan *et al*, 2020a, 2020b). In addition, isotope studies have also been developed in many groundwater basins, specifically using stable isotopes of ^{18}O and ^{2}H (D). Various hydrochemical and isotope methods have been developed in various groundwater basins but have not been widely used in hard water areas or not potential groundwater basins. For this reason, the author is interested in studying groundwater in hilly areas, considering that this area is a groundwater basin that is lacking in potential so that there has not been much in-depth hydrogeological (hydrochemical and hydroisotope) research in this area.

The area of research is administratively included in the area of Kulon Progo District, Special Region of Yogyakarta and Purworejo District, Central Java (Fig.1). Most of the western part of studied areas are included in Kaligesing Subdistrict, Purworejo District, while in the eastern part are included in Girimulyo Subdistrict, West Progo District. The land use of the areas is dominated by forest, garden, brush and empty land (Putranto & Aryanto, 2018), while settlements only be found rarely and locally.

By conducting chemical and natural isotope analysis, this study seeks to present a groundwater flow model in areas that are often referred to as non-groundwater basins, particularly in the Kulon Progo Dome. So far, studies on natural isotopes have never been carried out in this area. This isotope study is very important to help understand groundwater flow systems, as well as analysis of groundwater level mapping and hydrochemicals.

Figure 1: The location index map of the study area.

MATERIAL AND METHODS

Field Sampling and Laboratory Testing

The groundwater study began by conducting hydrogeological mapping in the field with observations on 35 wells and 40 springs. Each sample was taken twice, during the dry and rainy seasons. The groundwater samples were taken at selected springs of 14 samples to be tested for chemical and stable isotope contents. Those samples represented for Old Andesite and Jonggrangan Formations, each formation was represented by 7 samples in each season. All samples were taken from large discharge springs, because springs are a natural discharge, and can characterize the origin of groundwater flow. Dug wells are rare and unevenly distributed so that they are less representative to be tested in laboratory. However, observations were made on dug wells to determine groundwater levels and their quality. Monitoring has been done at least twice in a season, while sampling were taken in June, 2017 represents the dry season and in November 2017 represents the rainy season. Some field photos are shown in Fig. 2.

Figure 2: Clockwise from top left: Sikantong, Mudal, Clapar springs and andesite lava outcrops in Clapar. Both Sikantong and Mudal springs discharge water from the Jonggrangan Formation, while the Clapar Springs are found in the Old Andesite Formation.

Several parameters of physical/chemical characteristics which were measured in the field including temperature (T), acidity (pH), total dissolved solid (TDS), and electric conductivity (EC). These parameters were measured by thermometer, and Hana portable test kit (pH-meter, EC-meter and TDS-meter). The groundwater samples were filtered using 0.45 syringe and put in 500 ml polyethylene bottle for anion and 500 ml for cation analysis. Groundwater was acidified by 0.1 N HCl especially for cation samples to prevent precipitation in bottles.

The physical/chemical parameter of water samples has been tested in BBTKLPP Laboratory, Yogyakarta, Indonesian Ministry of Health. The test was carried out using the test method from the Indonesian National Standard (SNI) 2004-2009, in-house method and the 2012 APHA. The instrument used was the ion chromatography / spectrophotometer. The major ions were determined using chromatography and spectrophotometer equipment. According to Yuan *et al* (2017) the results can be ideal used with charge balance error less than 5%.

Whereas, the stable isotopes ^{18}O and ^{2}H are present in water in the form of $^{1}H_2{}^{18}O$ and $^{1}H^{2}H^{16}O$ compounds (Satrio *et al*, 2015). These two isotopes are very sensitive to physical processes such as evaporation and condensation, therefore to prevent this the sampling is carried out in the following manner.

a. The 30 ml water sample was put into an airtight (polyethylene) bottle by inserting the bottle into a water source.
b. Avoid the presence of air bubbles in the sample by inserting the sample slowly.
c. After the sample is completely filled and there are no air bubbles, the bottle is tightly closed until it is airtight (Satrio *et al*, 2015). To avoid interaction with the atmosphere and evaporation, plastic bottles are equipped with an inner cover (Satrio & Sidauruk, 2015).

Groundwater stable isotope test was conducted at the Hydrology Laboratory, Center for Isotope and Radiation Application (PAIR) - National Nuclear Energy Agency (BATAN), Jakarta. Isotope content in groundwater samples was determined using a Liquid Water Stable Isotope Analyzer (LWIA) type DLT-100 made by LGR (Los Gatos Research) USA. Isotope ratios were measured by a mass spectrometer and the results were referenced against the SMOW standard. The internal standards were calibrated using V-SMOW with analysis accuracy of ± 0.1 ‰ for $\delta^{18}O$ and ± 1 ‰ for δD.

Hydrochemical Analysis

Geological interpretation can be done by groundwater quality data. Some parameter have been analyzed include major ion and other parameter (pH, temperature, TDS and EC) in the field. The principle of this interpretation is based on the relations of the constituent ions of groundwater and is very useful for the purpose of analysis and synthesis (Swanson *et al*, 2001; Yidana *et al*, 2011). In addition, the groundwater characteristics are influenced by aquifer types (Harun *et al*, 2019).

Groundwater chemical analysis begins with reviewing the validity of groundwater chemical data using the ion balance method. Further analysis was carried out using several methods including the Kurlov and Chadha classification method (Ako *et al*, 2012), the Piper and Durov interpretation method (Lloyd & Heathcote, 1985), the Hiscock exploration method (Hiscock, 2005), the Gibbs diagram (Putranto *et al*, 2017) and the determination of the saturation index. Scatter plots of ions in groundwater are also carried out to see the effect of rocks on groundwater quality and their relationship to elevation and hydrochemical processes (Listyani, 2019).

Stable Isotope Analysis

Values $\delta^{18}O$ and δD and their range values can be used to see groundwater genesis (Satrio & Sidauruk, 2015). The content of this stable isotope in rainwater shows a linear relationship in the form of the global meteoric water line (GWML). Deviation from this line can be assessed to estimate groundwater genetics. The pattern of distribution of stable isotope contents can be analyzed to see the possibility of an isotopic evolutionary process in the groundwater flowing process in a groundwater basin. The relationship of stable groundwater isotope content to elevation and TDS can also be analyzed to determine the influential hydrochemical processes. In addition, an analysis of the enrichment of stable isotopes can be carried out to see the effects of seasonal changes on the content of these isotopes.

Evaluation is carried out based on compilation of field data, laboratory test results and assisted with some secondary data related to the substance of the study. The evaluation is based on a number of graphs used in the analysis as well as several maps generated from field and laboratory data in groundwater.

Data Verification

Primary data that have been obtained are then verified using statistical tests. The statistical method used in this study is the correlation regression method to see the relationship between two variables, as well as the average difference test to see whether there are differences in a variable in different aquifer systems (Jonggrangan Formation vs Old Andesite Formation).

RESULTS AND DISCUSSION

Hydrogeology of Study Area

The study area consists of Old Andesite and Jonggrangan Formations. The Old Andesite Formation is composed of volcanic rocks such as andesite breccias, tuffs, lapilli, agglomerates and intercalation of andesite lava. Andesite intrusion is also found, composed of hyperstene andesite to hornblende andesite augite and trachyandesite. Meanwhile, the Jonggrangan Formation is composed of layered limestone and coral limestone dominantly, tuff marl and limestone sandstones.

Geology in the study area is dominated by volcanic material such as andesite breccias and andesite lava flows. This material was formed by the existence of ancient volcanic activity during the Tertiary Period and is impermeable. As a result, this material is not able to store and flow water, so that groundwater reserves in this area are very small. The presence of groundwater in this area is often found in deep layers and is only found in rock fractures. Meanwhile, rocks from the Jonggrangan Formation in the study area are also dominated by compact limestones and provide groundwater through the crack pores in addition to the intergrain pores.

Hydrochemical and Isotopes Data

The results of chemical and isotope laboratory tests are shown in Table 1-2. In accordance with the Kurlov classification, all groundwater studied was bicarbonate water, with variations in Ca, Na and Mg cations. The stable isotope test results show variations of -8.2 to 4.77‰ for ^{18}O and -50.2 to -34.7‰ for D.

Table 1: Physical/chemical Data of Groundwater Samples Testing.

Table 2: Hydrochemical and Stable Isotopes Laboratory Tests Results.

Basic Groundwater Flow

The groundwater flow can be derived from groundwater table obtained from measurements in dug wells (Fig. 3). The groundwater flow pattern is in line with the direction of the morphological slope, that is, from a high elevation area to a lower place. However, the groundwater level and the slope of the study area only correlated with a moderate level of relationship. This means that the magnitude of the slope does not always affect the groundwater flow pattern. However, steep slopes often control the formation of depressed springs so that the groundwater flow pattern leads to the local discharge zone in that area.

Groundwater flows from a higher groundwater level to a lower one, then comes out as a discharge in springs or dug wells. Groundwater flows locally from higher to lower areas near springs or dug wells. In general, groundwater flow patterns flow in various directions, including northwest, southwest and south /

southeast. On a large scale (narrower areas) it is still possible to flow patterns in all directions following the local topography, for example to the north, east or west.

Figure 3: Map of the observation location and groundwater flow of the study area (Listyani *et al*, 2019).

Groundwater flow pattern based on hydrochemical characteristic

Various analyses have shown that groundwater develops in bicarbonate facies, with variations in the main cations Ca^{2+}, Na^{+}, and Mg^{2+}. The physical/chemical properties of groundwater which include temperature, pH, total dissolved solids (TDS) and EC have little changed due to the change of seasons.

In general, the type of groundwater chemistry studied is relatively stable, meaning that it is not easy to change with seasonal changes. This groundwater facies is the initial phase of the evolutionary process in which these facies are a type of water chemistry that is typical for catchment areas. Based on the Chadha classification (Listyani, 2019), the main dominance of the carbonate type is Ca, Mg-HCO_3 and does not change in different seasons.

The main ion content is dominated by bicarbonate anions. This anion is the dominant ion affecting the groundwater TDS value. The high bicarbonate content is usually associated with rainfall. Meanwhile, the main cations contained in groundwater are Ca^{2+} and Mg^{2+}. The Mg^{2+} concentration increases during the dry season.

The composition of groundwater is dynamic. This composition can change due to a reaction between water and rock minerals. The process can take place during the groundwater infiltration process, during the process of flowing in the aquifer until it emerges as a spring (Chebotarev, 1955 in Domenico & Schwartz, 1990). Groundwater chemical composition in the study area also shows a dynamic nature, with some changes in chemical facies from one place to another. The difference of groundwater hydrochemical facies under study lies in the difference in the dominance of the main cation content.

The interpretation of groundwater flow patterns can be done based on the dominance of the main ions as follows.

1. Based on the main anion:

   All groundwater samples show bicarbonate facies, meaning that groundwater flow patterns can begin (absorption zone) anywhere or end (discharge zone) in springs or dug wells anywhere.

2. Based on the main cation:

   In accordance with the sequences of Goldich (1938, in Appelo & Postma, 2005), the pattern of groundwater flow can be interpreted successively from the facies of Ca → Ca, Mg → Mg → Ca, Na.

Thus, groundwater flow patterns can be interpreted to run from Ca-HCO_3 → Ca, Mg-HCO_3 → Mg-HCO_3 facies to Ca,Na - HCO_3 facies in the dry season (Figure 4) and from Ca-HCO_3 → Ca,Mg - HCO_3 facies to the Ca,Na - HCO_3 facies in the rainy season (Figure 5).

Figure 4: Interpretation of groundwater flow patterns based on hydrochemical facies in the dry season.

Figure 5: Interpretation of groundwater flow patterns based on hydrochemical facies in the rainy season.

Groundwater in the Old Andesite Formation generally has a smaller primary ion content than in the Jonggrangan Formation. The main ion content is more groundwater in the Jonggrangan aquifer, while silica content is more in the Old Andesite Formation. Ca content is greater in the Jonggrangan Formation. This cation can be obtained from dissolving carbonate minerals or minerals in andesitic rocks such as Ca-plagioclase.

Hydrochemical processes have been determined by Chada, Piper, Durov, Hiscock as well as Gibbs diagrams. The results show that occur in groundwater flow systems in the study area are dominated by leaching, ion exchange, and sulfate reduction. In addition, the process of dilution by rainwater is also very important. The main ion content also shows the dominance of the influence of rocks dissolved in groundwater.

The rocks that consist of the study area affect the groundwater chemical content studied through the weathering and dissolving minerals. Weathered primary silicate minerals generally turn into kaolinite and montmorillonite so they are easily dissolved in the groundwater system. The silica content in groundwater is relatively small. This silica grows larger in the Old Andesite Formation, showing a fairly large water-rock interaction as well, related to the large water-rock ratio in the rainy season.

Statistical tests have been carried out to determine the normality and homogeneity of the data. The results show that the groundwater hardness in the Jonggrangan Formation aquifer system is different from those in the Old Andesite Formation aquifer system, which is proven for the dry season data, but not significantly for the rainy season (Table 3; see data in Table 1). Hardness (Hr.) value is calculated from the formula Hr = 2.5 Ca + 4.1 Mg (Todd, 1949, in Listyani, 2019).

Table 3: Groundwater hardness statistical test results

The statistical test of normality show that all TDS data in the dry and rainy seasons in the Old Andesite and Jonggrangan Formations are normally distributed (Table 4; see data in Table 1). Homogeneity test results in the dry season indicate that the data are homogeneous, but the data in the rainy season are not homogeneous. The difference in inhomogeneity in the rainy and dry seasons shows that the season affects groundwater's TDS. However, the results of different tests showed that groundwater TDS in all seasons had a significant difference between groundwater's TDS in the Old Andesite and Jonggrangan Formations. The results of this statistical test indicate that the groundwater TDS in the Jonggrangan aquifer system is different from that of the Old Andesite Formation aquifer system.

Table 4: The results of the groundwater TDS statistical test

Groundwater Flow Pattern Based on Stable Isotope Characteristic

Groundwater in some springs has light or heavy stable isotopes. The content of stable isotopes marks the system of deep groundwater flow or elevation of infiltration water that occurs in high areas. S4 (Njuboh), S13 (Sikantong) and S17 (Mudal) springs which are at a high elevation are examples of springs that receive recharge from local areas with higher elevation. S17 (Mudal) spring also has the possibility of being supplied by infiltration water from other places, characterized by a very light δD (reaching -50.2‰). Meanwhile, springs S29 (Kaligono; marked with light $\delta^{18}O$) and S39 (Kaligesing; marked by light $\delta^{18}O$ and D) at a lower elevation receive elevation from other higher elevation areas, for example from surrounding peaks/slopes.

High evaporation is marked by $\delta^{18}O$ which is experienced by S25 (Clapar) springs in the dry season and occurs in S1 (Munggangsari), S21 (Jatimulyo) and S25 (Clapar) springs in the rainy season. Some springs experience increased evaporation during the rainy season, marked by $\delta^{18}O$ values in the dry season and become heavier during the rainy season, including springs S11 (Pagertengah), S13 (Sikantong), S17 (Mudal), and S39 (Kaligesing). In addition to evaporation, this can also be caused by mixing with surface water that has evaporated before being infiltrated in groundwater.

If the groundwater regression line studied is close to the global meteoric water line (GMWL) and the local meteoric water line (LMWL), the groundwater is affected by the local climate or because of the topographic effects (Listyani, 2016). Groundwater regression lines adjacent to LMWL indicate that groundwater genetic originated from local precipitation (Figure 6a). Because this regression line is very close to the LMWL, enrichment of the isotope content of meteoric water is not yet clearly seen in this dry season. However, the presence of d-excess in the dry season is due to climate effects (Alam, 2014). Groundwater regression lines in the rainy season cross the LMWL line and do not resemble / close to LMWL (Figure 6b).

Figure 6: The relation between δD dan $\delta^{18}O$ of groundwater in dry (a) and rainy (b) seasons.

The regression line below the meteoric water line as shown in the figure shows isotopic enrichment (Alam, 2014). Several groundwater samples show plots below the LMWL which means that the groundwater has undergone isotopic enrichment, perhaps due to mixing with surface water/runoff or because the evaporation process is quite intensive.

Heavy δD values in all seasons occur at S25 (Clapar) springs of -38.3‰. Supported by partial shifting in this δD, groundwater flow in the Clapar area is interpreted as shallow groundwater flow. The $\delta^{18}O$ and δD values which are heavier in the dry season than in the rainy season as in spring S29 (Kaligono) show more intensive evaporation during the dry season.

The total shifted of δD values marks shallow groundwater flow systems such as in springs S7 (Anjani), S16 (Hulosobo), S17 (Mudal), S20 (Seplawan), S26 (Durensari) and S39 (Kaligesing). In addition to these springs, all springs experience partial shifting. This δD shifting indicates that groundwater flow patterns develop primarily in shallow aquifers. Deep flow patterns can occur in several springs, characterized by consistent, light δD and large δD-excess (d), including S13 (Sikantong), S14 (Ngelo), S17 (Mudal) springs.

Isotopic enrichment through evaporation occurs during the dry and rainy seasons. This isotopic enrichment is characterized by an increase in δD content and a relatively small d value, such as in S25 (Clapar) springs. During the rainy season, isotopic enrichment can also occur due to mixing with surface water that has undergone evaporation first. This mixing with surface water process is usually characterized by heavy and shifted δD, for example in S1 (Munggangsari) spring. δD enrichment occurs in the rainy season which marks evaporated surface water mixing also occurs in S11 (Pagertengah), S21 (Jatimulyo) and S25 (Clapar) springs.

A big and consistent value of d is found in spring S7 (Anjani) marking thin soil resulting in rapid infiltration. Anjani spring is more evaporated during the dry season, this is related to the warmer temperatures in that season. A big and consistent d value marks a rapid infiltration process, usually occurring in springs with the Jonggrangan Formation aquifer. Examples of these springs include S14 (Ngelo), S20 (Seplawan) springs. However, springs in the Old Andesite Formation can also experience this, for example in S26 (Durensari) spring.

A small value of d marks a high evaporation process, such as S16 (Hulosobo) springs in the rainy season. It shows the enrichment process which is more developed during the rainy season. S25 (Clapar) spring has a small d in all seasons, marking infiltration water that has undergone evapotranspiration before infiltration below the surface.

The interpretation of groundwater flow patterns based on stable isotope content can be made with the following considerations.

1. Based on ^{18}O stable isotope content.

Groundwater isotopic fractionation runs from light to heavy isotopes. Isotopic evolution resulting in an increase in $\delta^{18}O$ strongly supported by an increase in TDS (Listyani, 2016) is also evident in the study area. Therefore, groundwater flow patterns can be interpreted in accordance with the direction of enrichment of iso-^{18}O.

2. Based on the stable isotope content of D.

   Although the increase in δD is not followed by TDS, the enrichment of D isotope can be interpreted in line with the flow pattern, so long as the pattern does not conflict with the flow pattern based on $\delta^{18}O$.

3. Groundwater flow patterns are also made by considering the similarity of the range values in each spring compared to nearby springs. The similarity of the range values means that groundwater from springs having overlapping values is groundwater from the same source or the two springs are interconnected.

Synthesis of the groundwater flow system and pattern

The appearance of springs and groundwater flow patterns in the study area is part of the hydrogeological aspects of the study area which is included in the non groundwater basin or less potential groundwater basin. Groundwater can be found locally as wells and dug wells.

The dominance of bicarbonate ions in the groundwater studied shows that groundwater comes from local meteoric water, fresh and relatively young. This condition supports groundwater flow patterns in local/shallow systems. Groundwater flows in a not too long time, which means it has a short residence time. Chebotarev (1955, in Domenico & Schwartz, 1990) states that hydrochemical of groundwater is a reflection of residence time in the aquifer, where interactions can continue to occur until groundwater reach hydrochemical equilibrium. The short stay in the groundwater flow process in the study area is shown in the carbonate facies supported by low TDS content.

Groundwater Flow System

The results of this groundwater flow system synthesis concluded that the study area had a local groundwater system. Matters supporting the local groundwater system is explained as follows.

a. Based on hydrochemistry
   - The hydrochemical evolution of groundwater has not evolved yet, so it is not clear in changing groundwater facies. All locations in the study area show bicarbonate groundwater facies, which means they are in an early phase of evolution, where groundwater enters and exits in a short time and flows at short distances as well.
   - The weak correlation between TDS vs elevation indicates that evolution has not yet developed. In a basin, groundwater at low elevation generally will be more evolved (Ako *et al*, 2012), but

groundwater in the study area does not show a clear change in groundwater ion / TDS content to elevation.

b. Based on hydroisotopes

- Based on the stable isotope content it is known that groundwater comes from local precipitation and has not undergone significant isotopic evolution. This is indicated by an increase in groundwater isotope content which is not followed by an increase in TDS as well as spring elevation.
- The variation of $\delta^{18}O$ in the dry season is 1.89, while δD is 11.9 ‰ and increased to 3.43 ‰ for $\delta^{18}O$ and 21.9‰ for D. This significant variation of stable isotope content shows that the residence time is relatively short and the catchment area is not too far away (Satrio & Sidauruk, 2015).

This synthesis is also supported by the results of previous studies that revealed that groundwater generally develops in shallow aquifers (Budiadi *et al*, 2017) and local systems (Isnawan *et al*, 2017). The characteristics of shallow groundwater in the rainy season mostly tend to be near the meteoric line (Satrio *et al*, 2017).

Groundwater Flow Pattern

Groundwater flows through a fresh or half-weathered - weathered rock aquifer system into a colluvium deposit. The groundwater aquifers are mainly rocks from the Jonggrangan and Old Andesite Formations. Groundwater flowing on the Jonggrangan Formation rocks is generally controlled by porosity between grains, cracks, and channels due to the dissolution of carbonate minerals. Meanwhile, groundwater in the Old Andesite Formation is usually controlled by crack / joint porosity. The weathering process greatly helps the groundwater flow process in the groundwater flow system, so that the flow pattern develops in rocks that are starting to decay / half weathered.

The process of groundwater flow in the local system takes place at a short distance and a relatively short time. Local groundwater flows at short distances, enter the ground and exit through springs or wells. Infiltration can occur in the spring/well or in the surrounding area not far from the spring / well. However, groundwater flow patterns also develop in relatively fresh rocks, especially in the Jonggrangan Formation carbonate rock. In this case, groundwater flow maybe takes a longer trip if dissolving limestone channels or underground rivers are interconnected.

Based on a compilation of geological (Listyani *et al*, 2018, 2019), hydrochemical and stable isotope analysis, groundwater flow patterns can be made as follows (Figures 7 - 8). The groundwater flow map was done by data of grondwater table measured from dug wells, compiled with hydrochemical and isotopes analysis. The significant difference in groundwater flow occurs in deep flow between two seasons especially in the center of research area. There is a deep groundwater flow from Seplawan (S20) to Mudal

(S17) and continues toward Sikantong (S13) in rainy season. However, the deep groundwater is only interpreted beetween Jatimulyo (S21) to Seplawan.

Figure 7: Resume of groundwater flow pattern interpretation in the dry season.

Figure 8: Resume of groundwater flow pattern interpretation in the rainy season.

a. The shallow groundwater flow pattern is in accordance with the local topography (Listyani, 2019).
   - The flow pattern develops from the Ca-HCO_3 facies, then goes to Ca, Mg-HCO_3 then Mg-HCO_3 and finishes at the Ca, Na-HCO_3 facies.
   - Groundwater flow patterns are supported by enrichment of the ^{18}O and D. isotopes. If the direction of enrichment of the two isotopes is contradictory, then the enrichment of the ^{18}O isotope is preferred.
   - In the Jonggrangan Formation it is possible to have deep groundwater flow patterns through conduit porosity which can be interpreted based on isotope analysis, but still consider hydrochemical evolution. This deep groundwater flow pattern does not follow the local surface relief.
   - In the Old Andesite Formation, isotope analysis support can produce shallow groundwater flow patterns.

   Conformity of shallow groundwater flow with topography also applies to other areas in its vicinity (Listyani *et al*, 2017; Listyani & Budiadi, 2018).
b. Groundwater flow patterns with deep circulation, indicated by:
   - Hydrochemical groundwater with bicarbonate facies.
   - Isotope content is stable with consistent, light δD and big d.

For more details, the conceptual model of groundwater flow is briefly illustrated by the 3D block diagram in Figure 8 and the cross-section in Figure 9. The figure shows the pattern of groundwater flow in the West Progo Dome area that flows locally with almost the same variation in the dominant type of bicarbonate and light to heavy stable isotopic variations. Groundwater flow with deep circulation can be formed in the study area through the limestone cavities of the Jonggrangan Formation. The shallow groundwater flow may occur in many places to a depth of 20 m.

Figure 8: The 3D block diagram of groundwater model in the research area.

Figure 9: Hydrochemical and hydroisotopes cross-section.

CONCLUSION

Analysis of the hydrochemical and stable isotopes characteristics of groundwater in the central West Progo dome area resulted in findings of local groundwater flow systems and patterns. Hydrochemical characteristics in the study area show that groundwater has bicarbonate facies, neutral pH, low TDS, and EC. Hydrochemical processes include leaching, dissolution, ion exchange and sulfate reduction, but groundwater evolution has not developed yet.

Hydrochemical facies of groundwater is influenced by rock material due to water-rock interactions. Seasonal changes trigger hydrochemical characteristics changes. Meanwhile, the groundwater isotopes characteristics in the study area indicate that groundwater is supplied by rainwater with light to heavy isotopes contents. The isotopic evolution of groundwater is not yet clear. Changes in isotope content due to seasonal changes. Finally, the synthesis of groundwater flow systems in the study area results that the groundwater flows in the local system. The groundwater flow can be divided into two patterns types namely shallow and deep groundwater flow patterns, where deep groundwater flow patterns may develop in the Jonggrangan Formation aquifer.

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REFERENCES

Ako, A.A., Shimada, J., Hosono, T., Kagabu, M., Ayuk, A.R., Nkeng, G.E., Eyong, G.E.T. and Takounjou, A.L.F., 2012. Spring Water Quality and Usability in The Mount Cameroon Area Revealed by Hydrogeochemistry. Environ Geochem Health, 34, 615 – 639. Springer Science+Business Media B.V. https://doi.org/10.1007/s10653-012-9453-3.

Alam, B.Y.C.S.S.S., Itoi, R., Taguchi, S. & Yamashiro, R., 2014. Spatial Variation in Groundwater Types in Mt. Karang (West Java, Indonesia) Volcanic Aquifer System based on Hydrochemical and Stable Isotope δD and $\delta^{18}O$ Analysis. Modern Applied Science 8.6, p. 87-102.

Alam, B.Y.C.S.S.S., Itoi, R., Taguchi, S., Saibi, H., and Yamashiro, R., 2019. Hydrogeochemical and Isotope Characterization of Geothermal Waters from The Cidanau Geothermal Field, West Java, Indonesia. Geothermics, 78 (2019) 62-69. https://doi.org/10.1016/j.geothermics.2018.11.003.

Appelo C.A.J. and Postma, D., 2005. Geochemistry, Groundwater and Pollution, 2^{nd} Ed. A.A. Balkema, Amsterdam. 536 pp.

Budiadi, Ev., Listyani R.A., T. and Putro, C.U., 2017. Morphological Aspects on Spring Appearance at Girimulyo and Its Surrounding Area, West Progo. KURVATEK, 02, 2, 45-54. https://journal.sttnas.ac.id/krvtk/article/view/540/pdf.

Domenico, P.A. and Schwartz, F.W., 1990. Physical and Chemical Hydrogeology. John Wiley & Son, New York.

Harun, H.H., Roslan M.K., M., Nurhidayu, S., Ash'aari, Z.H. and Kusin, F.M., 2019. Hydrogeochemistry Investigation on Groundwater in Kuala Langat, Banting, Selangor. Bulletin of the Geological Society Malaysia, 67, 127-134.

Hiscock, K.M. 2005. Hydrogeology, Principles and Practice. United Kingdom: Blackwell Publishing Company.
Irawan, D.E., 2009. Hidrogeologi Cekungan Bandung. Geology Book of the Bandung Basin. Selected reading, Part 12.

Isnawan, D., Listyani R.A., T.and Noormansyah, F., 2017. Environmental Geological Potential of Kaligesing Area, Purworejo District. KURVATEK, 2, 2, 11-23. https://journal.sttnas.ac.id/krvtk/article/view/544/pdf.

Listyani R.A., T., 2016. Groundwater Flow and Its Isotopic Evolution in Deep Aquifer of Jakarta Groundwater Basin. Journal of Geological Sciences (JGS), 3, 1, DOI. 10.5176/2335-6774 3.1.25 , GSTF, Singapore, gstfjgsvol3no1@easychair.org; http://dl6.globalstf.org/index.php/jgs/ article/view/1633/1548

Listyani R.A., T., 2019. Groundwater Flow Model Based on Geology, Hydrochemical and Stable Isotope at Central West Progo Dome. Ph.D. Thesis, Padjadjaran University, Bandung.

Listyani R.A., T. and Budiadi, Ev., 2018. Groundwater Occurrence Prediction using Regressions on Morphometric Variables in Upstream Progo Watershed, Yogyakarta. Indonesian Journal of Geoscience, 5, 3, 265 -276. Geological Agency, Ministry of Energy and Mineral Resources. http://ijog.geologi.esdm.go.id.

Listyani R.A., T., Sulaksana, N., Alam, B.Y.C.S.S.S. and Sudradjat, A., 2017. Quantitative Geomorphology of Landform at Samigaluh and Surrounding Area, West Progo, Central Java, Indonesia. The [2]nd Joint Conference of Utsunomiya University and Universitas Padjadjaran, Utsunomiya, Japan. https://uuair.lib.utsunomiya-u.ac.jp/dspace/bitstream/10241/10929/1/technical+session_pro_5.pdf.

Listyani R.A., T., Sulaksana, N., Alam, B.Y.C.S.S.S., Sudradjat, A, and Haryanto, A.D., 2018. Lineament Control on Spring Characteristics At Central West Progo Hills, Indonesia. International Journal of GEOMATE, 14, 46, 177-184. https://doi.org/10.21660/2018.46.70127.

Listyani R.A., T, Sulaksana, N., Alam, B.Y.C.S.S.S. and Sudradjat, A., 2019. Topographic Control on Groundwater Flow in Central of Hard Water Area, West Progo Hills, Indonesia. International Journal of GEOMATE, 17, 60, 83-89. https://doi.org/10.21660/2019.60.8104.

Lloyd, J.W. & Heathcote, J.A., 1985. Natural Inorganik Hydrochemistry in Relation to Groundwater, an Introduction. Oxford: Clarendon Press.

Mera, M. and F. Rantoso, 2019. Overcoming Flood in Batang-Takun Downstream Using Numerical Simulation". International Journal on Advance Science Engineering Information Technology, 9, 4, 1260-1268. https://doi.org/10.18517/ijaseit.9.4.8934.

Meteorology Climatology and Geophysics Council, 2018. Weather Forecast. https://www.bmkg.go.id.

Putranto, T.T. and Aryanto, D.E., 2018. Spatial Analysis to Determine Groundwater Recharge Area in Purworejo Regency, Central Java Province/Indonesia. ICENIS 2018, E3S Web of Conferences 73, 03025 (2018), https://doi.org/10.1051/e3sconf/20187303025.

Putranto, T.T., Hidajat, W.K., and Wijaya, H., 2017. Hydrochemical Assesment of Unconfined Aquifer System in Bayat Melange Complex, Klaten, Indonesia. International Journal of GEOMATE, Vol. 13, Issue 39, pp.17-24.

Satrio, Prasetio, R., Hadian, M.S.D. and Syafri, I., 2017. Stable Isotopes and Hydrochemistry Approach for Determining the Salinization Pattern of Shallow Groundwater in Alluvium Deposit Semarang, Central Java. Indonesian Journal on Geoscience, 4, 1, 1-10. https://doi.org/10.17014/ijog.4.1.1-10,

Satrio and Sidauruk, P., 2015. Studi Daerah Imbuh Sistem Air Sungai Bawah Tanah Gunungkidul Yogyakarta Menggunakan Isotop Stabil $\delta^{18}O$ dan $\delta^{2}H$. Jurnal Ilmiah Aplikasi Isotop dan Radiasi, 11, 2, 87 - 97.

Setiawan, T., Alam, BYCSSSA., Haryono, E. and Hendarmawan, 2020a. Hydrochemical and Environmental Isotopes Analysis for Characterizing A Complex Karst Hydrogeological System of Watuputih Area, Rembang, Central Java, Indonesia Hydrogeology Journal, 28, 1635–1659 (2020). https://doi.org/10.1007/s10040-020-02128-8.

Setiawan, T., Alam, BYCSSSA., Haryono, E., and Hendarmawan, 2020b. Spatio-temporal Variation of Karst Spring Parameters for Characterizing of The Aquifer System of Watuputih Area, Indonesia. Journal of Water and Land Development, 45 (IV-VI) p. 143-156. https://doi.org/10.24425/jwld.2020.133056.

Swanson, S.K., Bahr, J,M,, Schwar, M,T,, Potter, K.W., 2001 Two-way cluster analysis of geochemical data to constrain spring source waters. Chem Geol 179:73–91.

Yidana, S.M., Banoeng-Yakubo, B., Akabzaa, T.M. 2010., Analysis of groundwater quality using multivariate and spatial analyses in the Keta basin, Ghana. J Afr Earth Sci 58:220–234. https://doi.org/10.1016/j.jafrearsci.2010.03.003.

Yuan, J., Xu, F., Deng, G., Tang, Y., Li, P., 2017. Hydrogeochemistry of shallow groundwater in a karst aquifer system of Bijie City, Guizhou Province. Water, 9:625. https://doi.org/10.3390/w9080625.

TABLE ATTACHMENTS

Table 1

No	Parameter (mg/l)	S1 Munggangsari	S4 Njuboh	S7 Anjani	S11 Pagertengah	S13 Sikantong	S14 Ngelo	S16 Hulosobo	S17 Mudal	S20 Seplawan	S21 Jatimulyo	S25 Clapar	S26 Durensari	S29 Kaligono	S39 Kaligesing
DRY SEASON															
1	Ca^{2+}	21,49	6,4	19,9	58,9	26,27	36,00	12,8	80,4	58,9	67,66	20,7	42,98	36,00	23,2
2	Na^{+}	22	6	10	13	11	5	15	6	6	8	21	25	21	18
3	K^{+}	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	Mg^{2+}	45,46	2,92	26,6	19,83	30,95	11,66	3,4	4,35	23,7	2,42	6,28	21,28	8,26	7,78
5	HCO_3^{-}	283,9	30	207,4	298,6	193,3	122	60,4	302,8	235,5	289,9	114,8	199,3	109,8	97,6
6	SO_4^{2-}	7	5	9	10	19	5	7	6	5	7	5	10	30	20
7	Cl^{-}	2	2,5	3,5	3	3	2,5	5	2	5	3	3	5	3,0	3,5
8	TDS	212	60	131	302	165	240	64	229	186	229	85	166	205	169
9	Hr.	240,11	27,97	158,81	228,55	192,57	137,81	45,94	218,84	244,42	179,07	77,5	194,7	123,87	89,9
RAINY SEASON															
1	Ca^{2+}	60,5	7,2	34,23	29,45	36,62	84,8	9,55	60,5	42,19	26,27	20,7	35,02	27,2	17,6
2	Na^{+}	21	9	6	8	6	6	12	5	5	5	20	19	17	14
3	K^{+}	1	<1	1	1	1	<1	2	1	<1	<1	2	1	<1	<1
4	Mg^{2+}	18,38	2,43	6,77	21,28	6,28	7,78	5,32	9,67	3,87	19,82	6,77	7,74	5,35	5,35
5	HCO_3^{-}	274,5	48,8	183	402,6	164,7	286,7	61	237,9	225,7	256,2	134,2	173,9	146,4	115,9
6	SO_4^{2-}	7	<1	7	13	14	7	8	6	6	6	6	8	10	9
7	Cl^{-}	3	3,5	3	2,5	4	2,5	5,5	4	2	2	4,5	2,5	1	1
8	TDS	206	35	128	234	126	217	50	198	216	215	89	123	91	71
9	Hr.	226,61	27,96	113,33	160,87	117,3	243,9	45,69	190,9	121,34	146,94	79,51	119,28	89,94	65,94

Table 2

No	Code	Location	Hydrochemical Facies		Stable isotope			
			Dry	Rainy	Dry		Rainy	
					^{18}O (‰)	D (‰)	^{18}O (‰)	D (‰)
1	S1	Munggangsari	$Mg\text{-}HCO_3$	$Ca, Mg\text{-}HCO_3$	-7,4 ± 0,44	-42,1 ± 3,0	-4,96 ± 0,18	-45,7 ± 1,6
2	S4	Njuboh	$Ca, Mg\text{-}HCO_3$	$Ca, Na\text{-}HCO_3$	-7,25 ± 0,26	-45,5 ± 2,1	-7,83 ± 0,51	-42,7 ± 4,4
3	S7	Anjani	$Ca, Mg\text{-}HCO_3$	$Ca\text{-}HCO_3$	-6,84 ± 0,20	-42,2 ± 0,9	-7,37 ± 0,35	-48,3 ± 3,1
4	S11	Pagertengah	$Ca, Mg\text{-}HCO_3$	$Ca\text{-}HCO_3$	-7,34 ± 0,42	-43,1 ± 2,1	-5,84 ± 0,47	-46,9 ± 2,1
5	S13	Sikantong	$Ca, Mg\text{-}HCO_3$	$Ca\text{-}HCO_3$	-7,4 ± 0,18	-46,6 ± 1,3	-6,72 ± 0,22	-49 ± 2,2
6	S14	Ngelo	$Ca, Mg\text{-}HCO_3$	$Ca\text{-}HCO_3$	-6,6 ± 0,38	-39,3 ± 2,4	-7,69 ± 1,09	-46,3 ± 7,1
7	S16	Hulosobo	$Ca, Na\text{-}HCO_3$	$Ca, Mg\text{-}HCO_3$	-6,88 ± 0,20	-41,1 ± 1,5	-6,78 ± 0,31	-48,5 ± 1,1
8	S17	Mudal	$Ca\text{-}HCO_3$	$Ca\text{-}HCO_3$	-7,39 ± 0,42	-45,1 ± 3,1	-6,94 ± 0,39	-50,2 ± 1,5
9	S20	Seplawan	$Ca, Mg\text{-}HCO_3$	$Ca\text{-}HCO_3$	-6,72 ± 0,12	-38,9 ± 1,6	-7,22 ± 0,61	-44,6 ± 1
10	S21	Jatimulyo	$Ca\text{-}HCO_3$	$Ca, Na\text{-}HCO_3$	-7,39 ± 0,13	-41,2 ± 1,5	-5,17 ± 0,26	-41,9 ± 1,4
11	S25	Clapar	$Ca, Na\text{-}HCO_3$	$Ca, Mg\text{-}HCO_3$	-5,51 ± 0,32	-34,7 ± 1,0	-4,77 ± 0,34	-38,3 ± 3
12	S26	Durensari	$Ca, Mg\text{-}HCO_3$	$Ca\text{-}HCO_3$	-6,45 ± 0,21	-36,8 ± 1,7	-7,11 ± 0,15	-46,9 ± 3
13	S29	Kaligono	$Ca\text{-}HCO_3$	$Ca\text{-}HCO_3$	-6,45 ± 0,03	-38,8 ± 0,4	-7,8 ± 1,11	-45,6 ± 6,6
14	S39	Kaligesing	$Ca, Mg\text{-}HCO_3$	$Ca, Mg\text{-}HCO_3$	-6,8 ± 0,91	-41,3 ± 1,6	-8,2 ± 1,23	-47,1 ± 1

Table 3

Season	Normality	Homogeneity	Different Test
Dry	Normal distribution	Homogeneous	There is a significant difference between groundwater in the Old Andesite and Jonggrangan Formations.
Rainy			There is no significant difference between groundwater in the Old Andesite and Jonggrangan Formations.

Table 4

Season	Normality	Homogeneity	Different Test
Dry	Normal distribution	Homogeneous	There is a significant difference between groundwater in the Old Andesite and Jonggrangan Formations
Rainy		Heterogeneous	

(Note: Data set for Table 3 & 4 is provided in Table 1)

ILLUSTRATIONS

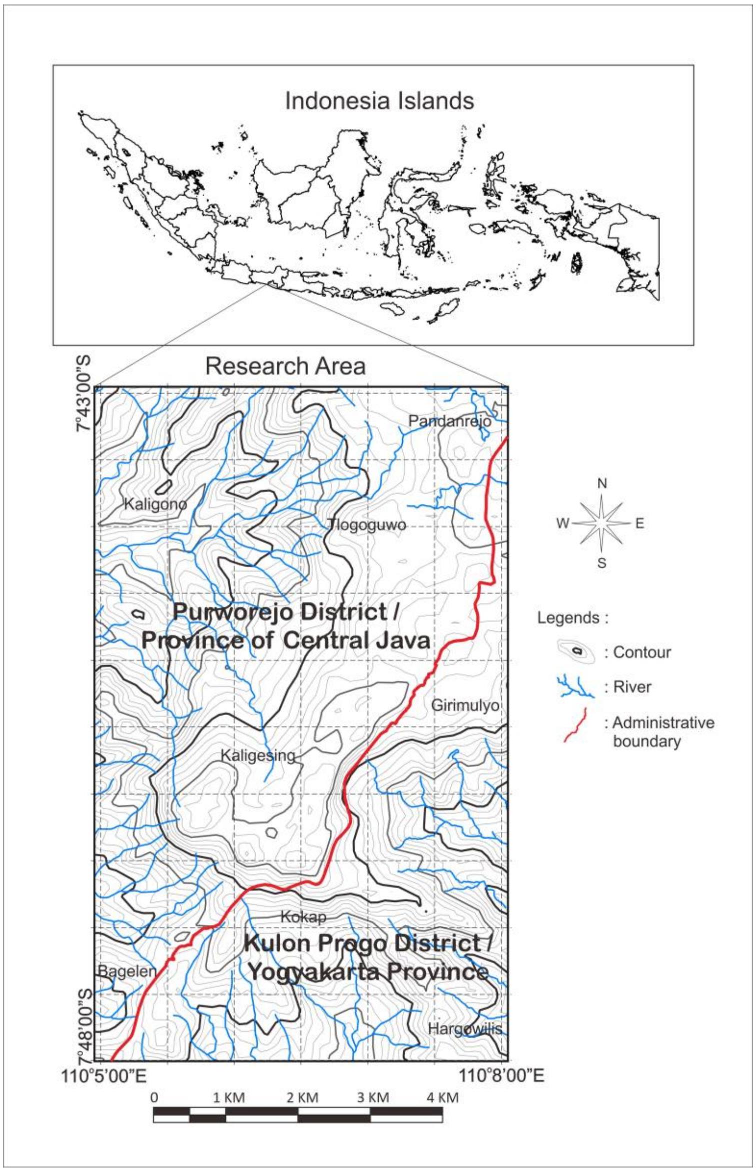

Figure 1: The location index map of the study area.

Figure 2: Clockwise from top left: Sikantong, Mudal, Clapar springs and andesite lava outcrops in Clapar. Both Sikantong and Mudal springs discharge water from the Jonggrangan Formation, while the Clapar Springs are found in the Old Andesite Formation.

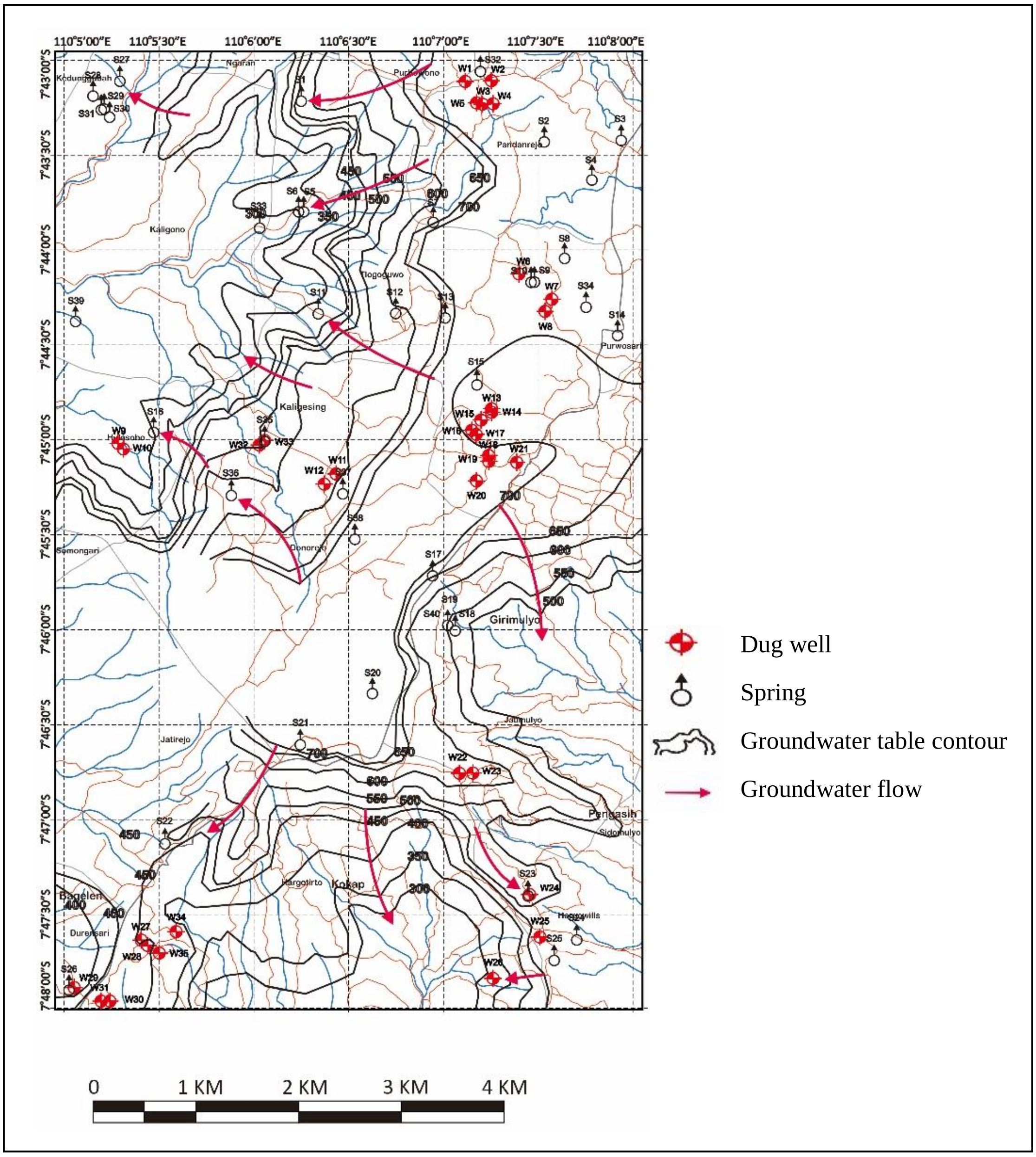

Figure 3: Map of the observation location and groundwater flow of the study area (Listyani *et al*, 2019).

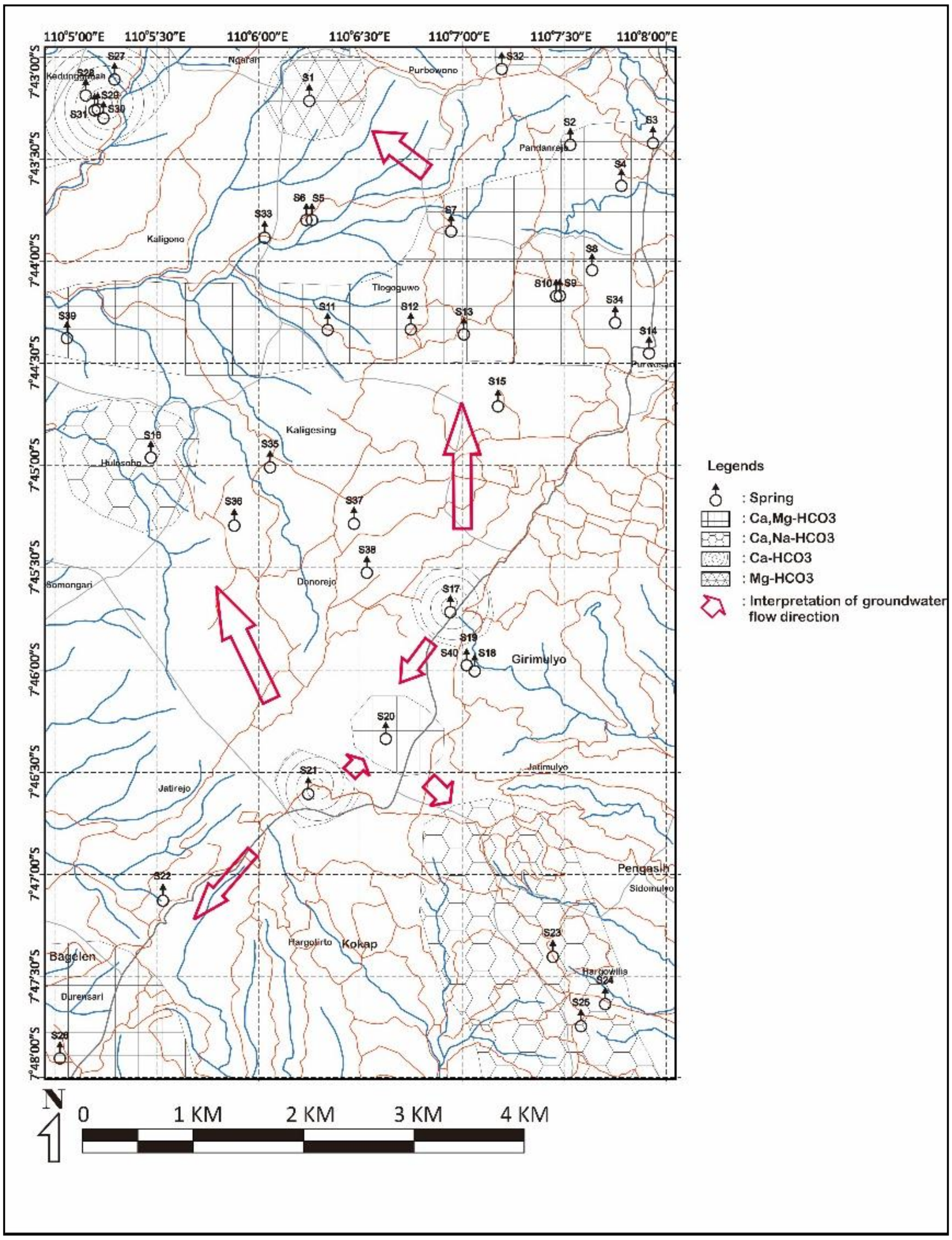

Figure 4: Interpretation of groundwater flow patterns based on hydrochemical facies in the dry season.

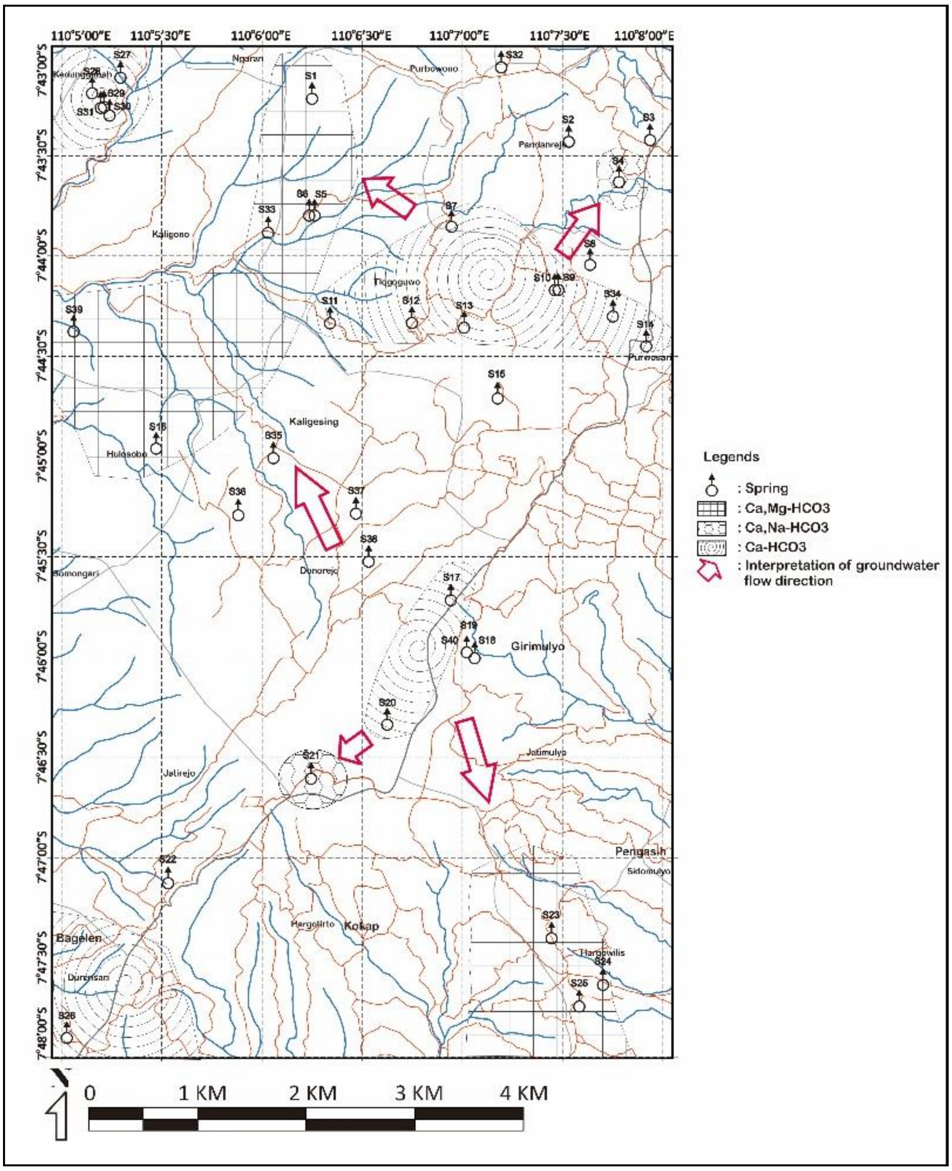

Figure 5: Interpretation of groundwater flow patterns based on hydrochemical facies in the rainy season.

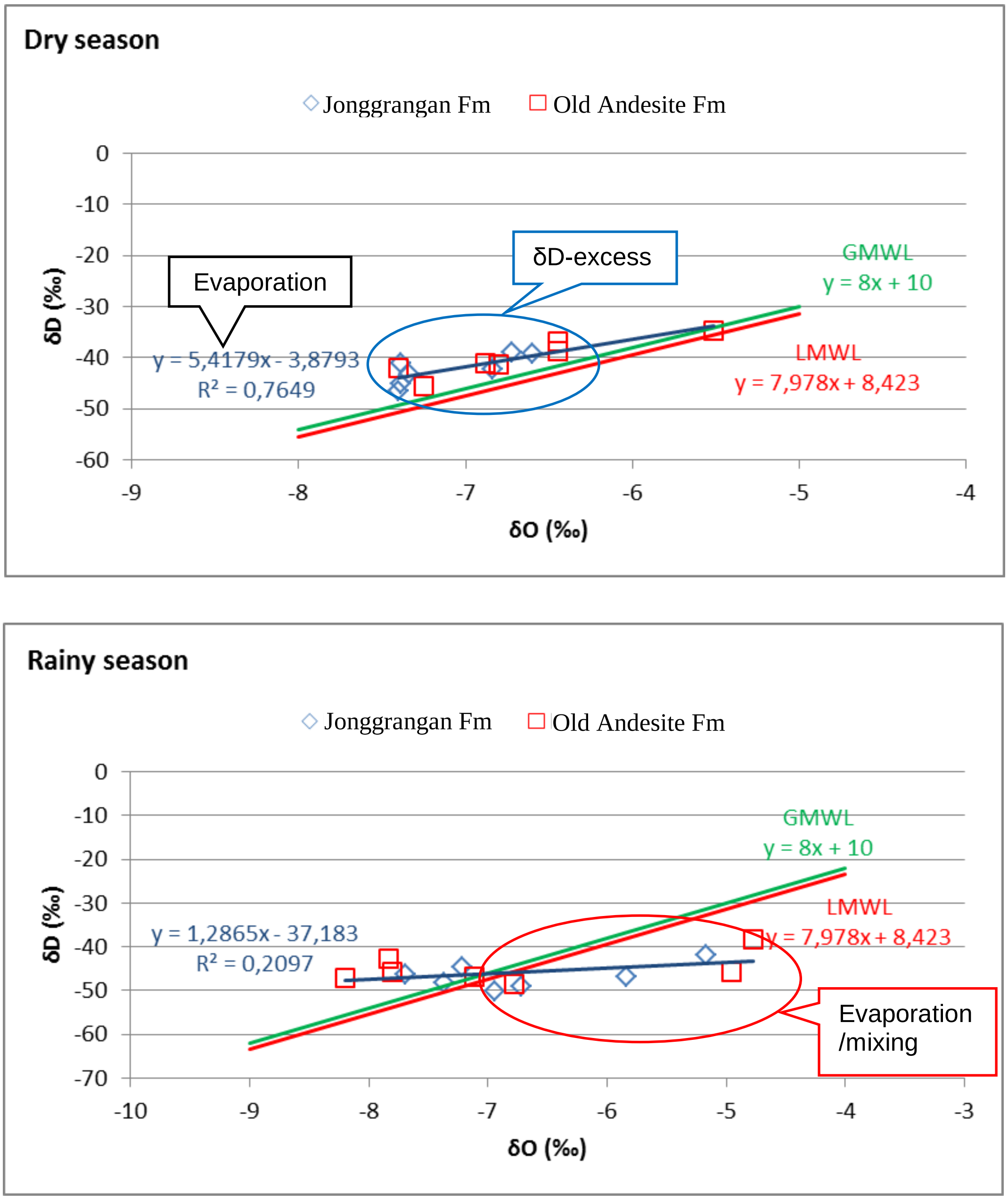

Figure 6: The relation between δD dan $\delta^{18}O$ of groundwater in dry and rainy seasons.

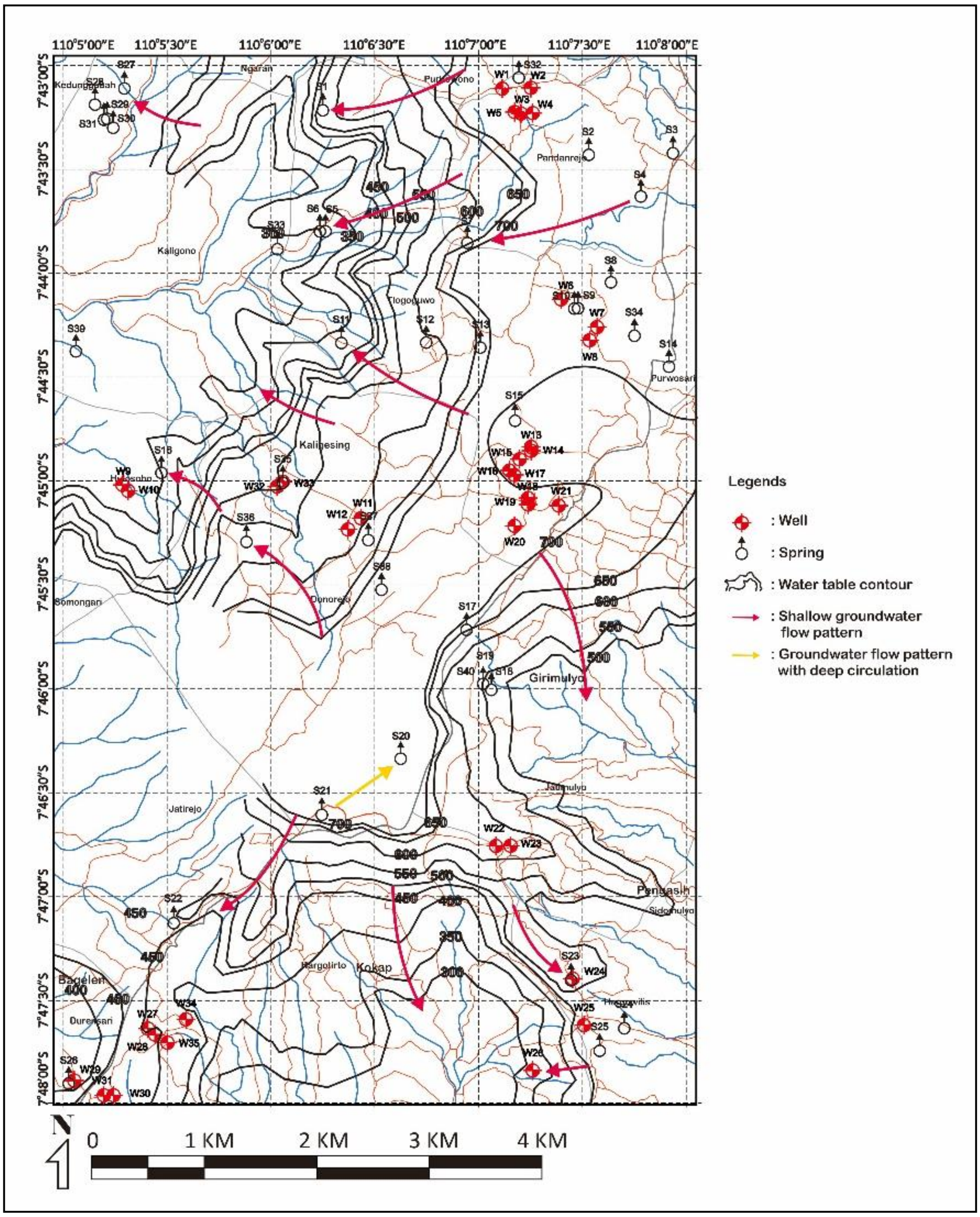

Figure 7: Resume of groundwater flow pattern interpretation in the dry season.

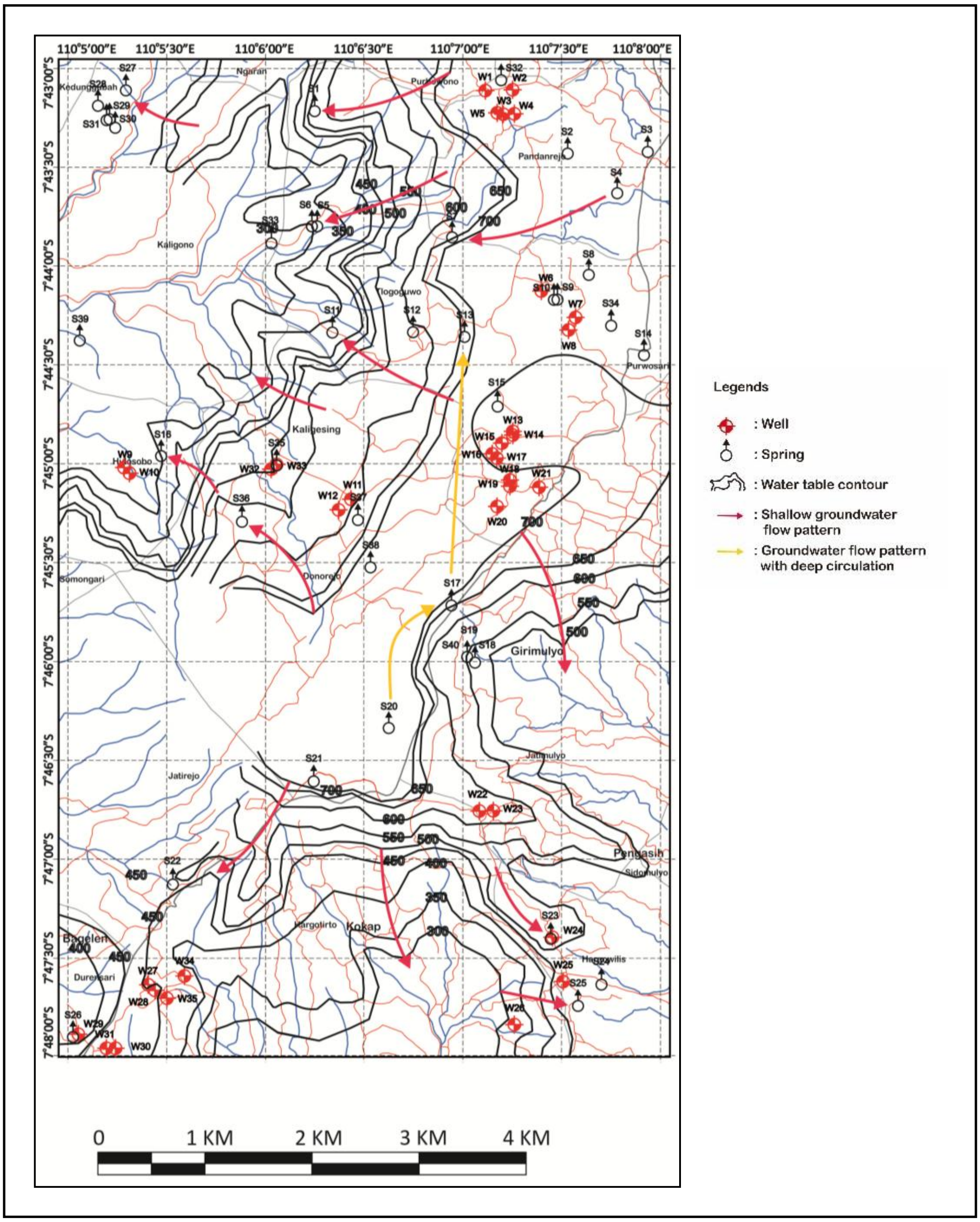

Figure 8: Resume of groundwater flow pattern interpretation in the rainy season.

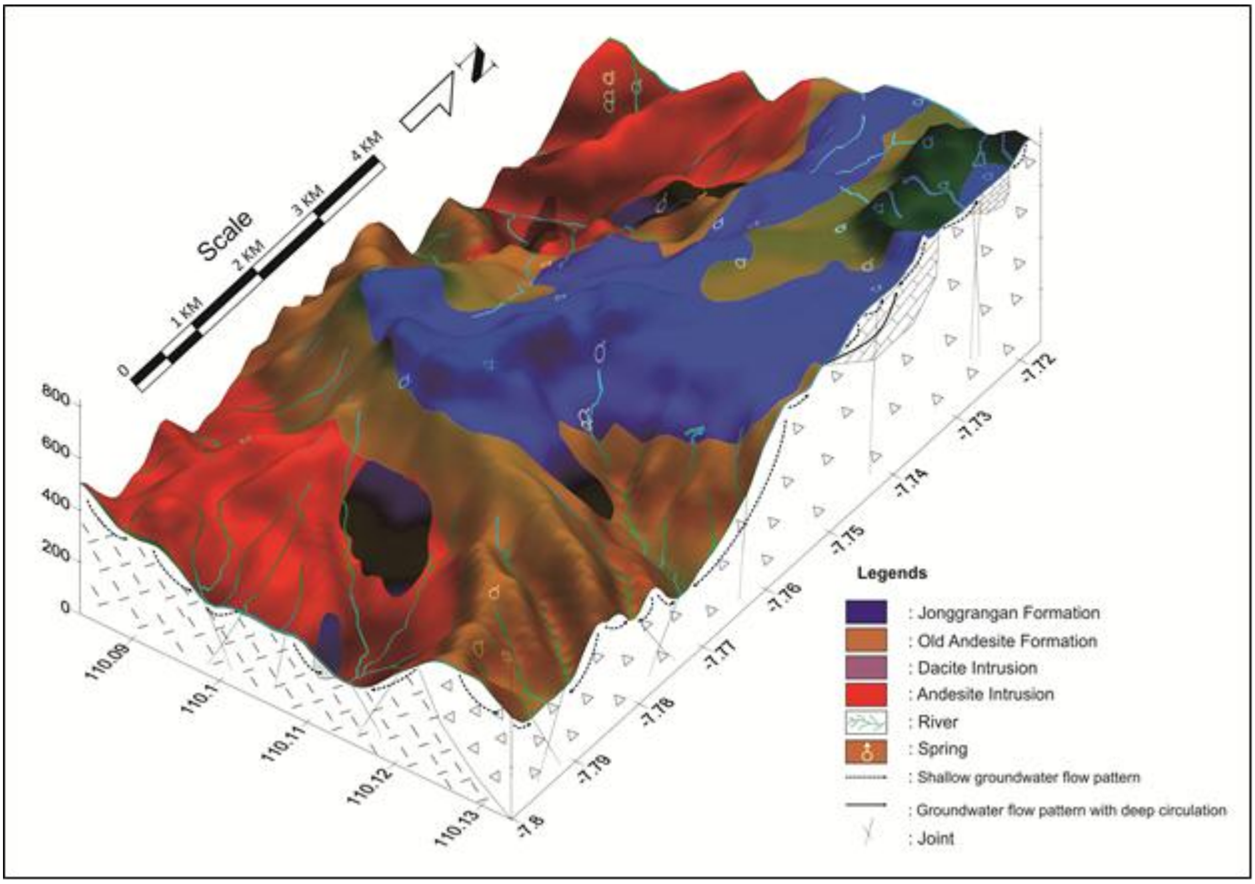

Figure 9: The 3D block diagram of groundwater model in the research area.

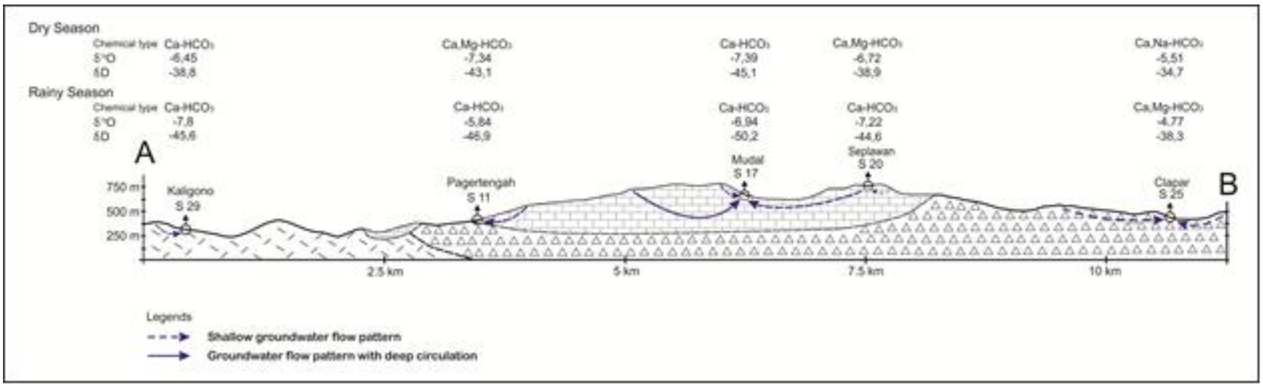

Figure 10: Hydrochemical and hydroisotopes cross-section.

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Status of Manuscript Submitted To The Geological Society Of Malaysia

Wan Aida <aidaawann@gmail.com> 27 Agustus 2020 08.09
Kepada: listyani theo <listyanitheophila@gmail.com>

Dear Ms Listyani,

Thank you for the submission of your corrected manuscript.
The editorial committee will review the manuscript again and you will be informed of its status as soon as possible.
[Kutipan teks disembunyikan]

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listyani theo <listyanitheophila@gmail.com>

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Wan Aida <aidaawann@gmail.com> 27 Agustus 2020 08.09
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Status of Manuscript Submitted To The Geological Society Of Malaysia

Wan Aida <aidaawann@gmail.com> 3 Oktober 2020 19.18
Kepada: listyani theo <listyanitheophila@gmail.com>, Geological Society of Malaysia <geologicalsociety@gmail.com>

Dear Ms Listyani,

In reference to your revised manuscript submitted on 21 August 2020, please find below comments from the Editorial Committee:

1 - Figure 1 : Need to add the well and spring locations and the bedrock geology.

2 - Materials And Method : The method of analysis of the spring water is not mentioned.

3 - Result And Discussion : Important to add the geology and hydrogeology of the study area.

Based on these comments, please update your manuscript accordingly and resubmit.

Thank you.
[Kutipan teks disembunyikan]

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Status of Manuscript Submitted To The Geological Society Of Malaysia

listyani theo <listyanitheophila@gmail.com> 17 Oktober 2020 13.12
Kepada: Wan Aida <aidaawann@gmail.com>

Dear editor,
Here I send the revision manuscript again. I hope this manuscript can be accepted and be published soon.Thank you so much.
Best regards,
Lis, Yogya, Indonesia
[Kutipan teks disembunyikan]

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listyani theo <listyanitheophila@gmail.com>

Manuscript: Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics

Wan Aida <aidaawann@gmail.com> 24 Oktober 2020 11.58
Kepada: listyani theo <listyanitheophila@gmail.com>, Geological Society of Malaysia <geologicalsociety@gmail.com>

Dear Ms. Listyani,

In reference to your revised manuscript entitled '**Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics**', we are pleased to inform you that the submission has been accepted for publication in Bulletin of the Geological Society of Malaysia.

Attached please find the Manuscript Acceptance Letter for your attention.

Thank you for your contribution to the Society's publication.

Yours sincerely,
Wan Aida
for the Editor BGSM

MS Acceptance Letter.docx
50K

Gmail

listyani theo <listyanitheophila@gmail.com>

Paper In Bull. GSM - Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics

Wan Aida <aidaawann@gmail.com> 31 Maret 2021 07.00
Kepada: listyani theo <listyanitheophila@gmail.com>, Geological Society of Malaysia <geologicalsociety@gmail.com>

Dear Ms Listyani,

Please find attached the formatted copy of your manuscript entitled ***'Groundwater flow model in the center of West Progo Dome based on hydrochemical and isotopic characteristics***' which will be published in Bull. of the GSM of May 2021.

Please check the attached proof and annotate with a Sticky Note any corrections you may have. Please note that there are several blurry photographs and illustrations that are marked by the Editor, kindly replace them with higher resolution photos / diagrams / texts.

As we would be finalizing the Bulletin soon, we would appreciate it if you could return the updates and edited proof before 10 April 2021.

Thank you.

Yours sincerely,
Wan Aida
for the Editor, BGSM

DRAFT - Groundwater flow model in the center of West Progo Dome.pdf
4813K

Gmail **listyani theo <listyanitheophila@gmail.com>**

Paper in GSM Bulletin May 2021: Acknowledgement To Reviewers

Wan Aida <aidaawann@gmail.com> 23 Mei 2021 07.00
Kepada: listyani theo <listyanitheophila@gmail.com>

Dear Dr Listyani,

With regard to your manuscript in the May Bulletin, kindly be informed that the Editor suggests that the study area locality is added to the title and in the first line of the abstracts (please refer to the attached draft). Further, we would also like you to add a few words to acknowledge the two anonymous reviewers who had reviewed your manuscript.

Thank you for your cooperation.

Yours sincerely,
Wan Aida

Paper 18.pdf
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Gmail

listyani theo <listyanitheophila@gmail.com>

Paper in GSM Bulletin May 2021: Acknowledgement To Reviewers

listyani theo <listyanitheophila@gmail.com> 23 Mei 2021 14.03
Kepada: Wan Aida <aidaawann@gmail.com>

Dear Editor
Thank you for your email. Attached is my revised manuscript according to your comments.
Thank you,

Best regards,
Lis
ITNY, Indonesia
[Kutipan teks disembunyikan]

Paper 18 revised 23 May 2021.pdf
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