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Hydrostratigraphy And Geometric Configuration of The Aquifer System of The Palu Groundwater Basin

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Abstract
Hydrostratigraphy and aquifer geometry in this study are limited to the configuration of the aquifer system which includes the determination of the lateral and vertical distribution of aquifers and non-aquifers that have relatively similar hydraulic characteristics and are grouped into one aquifer system. Aquifer geometry modeling is a 3D modeling to determine the subsurface aquifer of a Palu Groundwater Basin. The research method for determining the configuration of the aquifer system, using geological maps of the Palu area and its surroundings, maps of the Palu Groundwater Basin supported by groundwater characteristic data in the field. Data collection techniques for groundwater characteristic data using survey methods. The data processing uses a geospatial analysis approach using Arcgis and Map Info. The results of the study show that 1). In terms of aquifer geometry, the determination of the boundaries of the Palu Groundwater Basin is carried out through the identification of the types of groundwater basin boundaries, namely hydraulic boundaries controlled by geological and hydrogeological conditions. 2). The spatial distribution of the aquifer system based on the integration of geomorphological and geological approaches shows that the lateral distribution of the aquifer is determined by geomorphological conditions and vertically by geological conditions, 3). Hydrostratigraphically, the Palu Groundwater Basin serves as a boundary separating surface water flow, or the boundary of the Palu River Basin. Geomorphologically, it is the lateral boundary of the basin and geologically, it represents the vertical boundary of groundwater flow (flow-controlled boundaries), along the slopes of the structural hills of Mount Gawalise in the west and Mount Tanggungguno in the east of the Palu Groundwater Basin.

Keywords: *groundwater; aquifer; geometric; hydrostratigraphy; configuration*

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I. INTRODUCTION

Groundwater studies can be conducted using an environmental geospatial approach, namely: spatial analysis, ecological analysis, and regional complex analysis [1]. The spatial approach is a perspective or analytical framework that emphasizes the existence of space. Based on the condition of the landform, groundwater consists of: groundwater in alluvial plains, groundwater in detrial fans, groundwater in diluvial terraces, groundwater at the foot of volcanoes and groundwater in fractured rock zones [2],[3]. Groundwater is water stored in aquifers in a groundwater basin, which is influenced by geological conditions, hydrogeology, tectonic forces and the structure of the earth that forms the basin [4].

The Palu Basin of Central Sulawesi with an area of + 3,481 km2, administratively includes: part of Palu City, Sigi Regency, and Donggala Regency. The spatial and temporal distribution of groundwater, the existence of geomorphological and geological control factors, and considerations of groundwater utilization, therefore the research is focused on the Palu Groundwater Basin (CAT Palu) with an area of + 474.60 km2 [5]. Based on the hydrogeological concept, the study area is included in the Palu Groundwater Basin. Administratively it includes Palu City, as the Capital of Central Sulawesi Province, which is located between 0.350 - 1.200 N and 1200 - 122.090 E, with an area of 395.04 km2. The configuration of the aquifer system to determine the vertical distribution of the aquifer based on the hydrogeological cross section is sourced from the Directorate of Geology and Environmental Management, 1994 [5]. The Palu Basin is part of the Palu River Basin with one large branch, the Gumbasa River. The upstream part of this river, which is located in the southern part, is partly a lake, namely Lake Lindu which is located at an altitude of + 970 meters above sea level. The occurrence of the Palu Basin itself is thought to be closely related to the formation of geological structures in this region, namely the Palu fault which is trending north - south and other faults which are trending northwest - southeast. The subsidence of the rock body caused by this fault has resulted in the formation of a basin 8-10 km wide, + 50 km long with a northwest - southeast direction [4], [5]. Figure 1 bellow shows groundawer basin in Sulawesi.

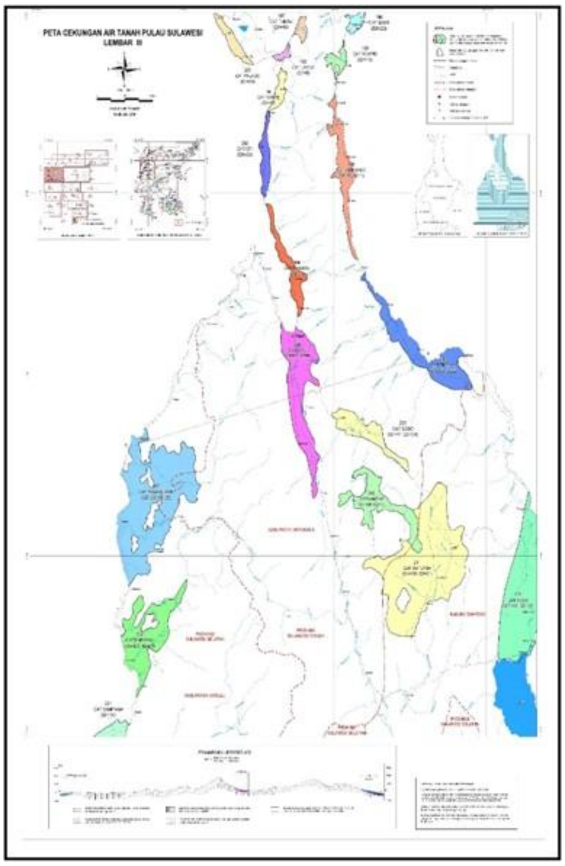

Figure 1: Groundwater Basins in Sulawesi

II. RESULT AND DISCUSSION

Aquifer geometry modeling is a 3D modeling to determine the subsurface aquifer of a CAT [6]. This modeling is done using GMS software. The research method for determining the configuration of the aquifer system, using geological maps of the Palu area and its surroundings, maps of the Palu Groundwater Basin supported by groundwater characteristic data in the field. Data collection techniques for groundwater characteristic data using survey methods. Data processing with a geospatial analysis approach using Arcgis and Map Info. This activity includes determining the lateral and vertical distribution of the aquifer [7],[8]. Determination of the lateral distribution of aquifers and non-aquifers is presented in the form of a thematic groundwater map [12], [14]. Determination of the vertical distribution of aquifers and non-aquifers that have relatively the same hydraulic characteristics and are grouped into one system based on: hydrogeological cross-sections and determining the depth of the upper and lower parts of the aquifer system [9], [10], [11]. Shows in Figure 2 geological map of the Palu Groundwater Basin.

Geologically, the Palu CAT is limited by the Oblique Fault in the West and East. The Miocene fault cuts the west, east, and south of the Palu CAT, which then makes the Palu CAT descend and cut the Tmpi Formation and Kls Formation, some of which become the base and aquitard on the slopes of the Palu CAT [13], [15], [17]. In the Pleistocene, the Celebe Sarasin Molasse (Qtms) was deposited, which unconformably overlies older rocks, and in the Holocene, alluvial deposits and beach deposits were deposited, which unconformably overlie the Celebe Sarasin Molasse [4].

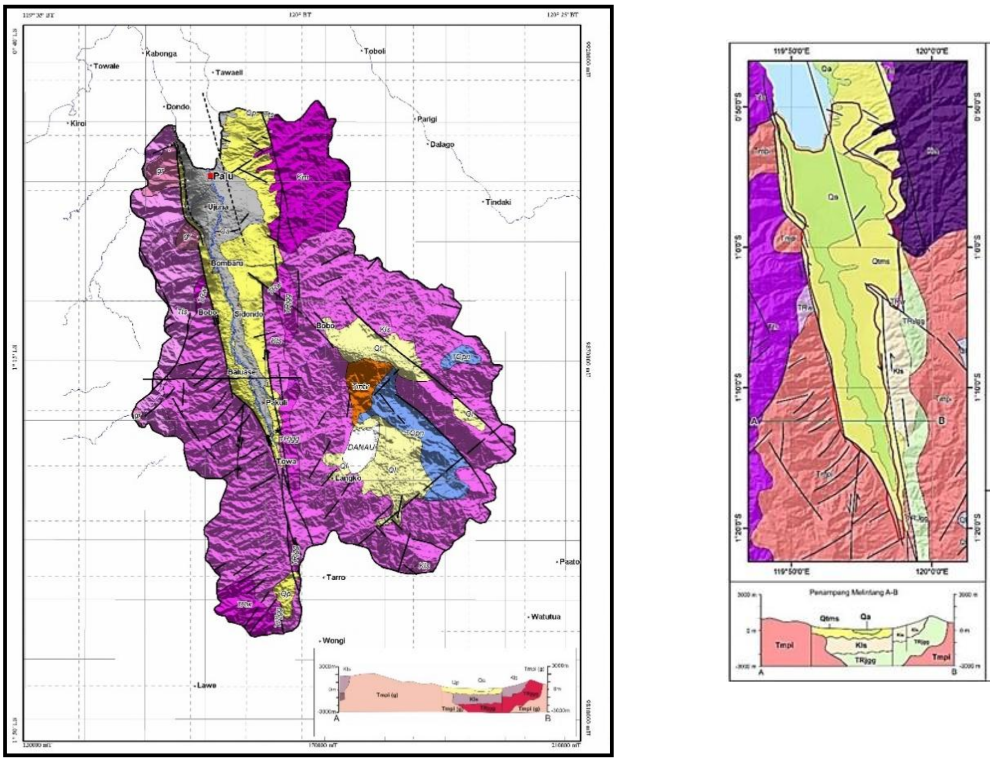

Figure 2: Geological Map of the Palu Groundwater Basin

Determining the lateral and vertical distribution of aquifers and non-aquifers indicates the configuration of the aquifer system [16]. Groundwater analysis encompasses a wide range of topics, including aquifer type, aquifer parameters that indicate aquifer characteristics, and its utilization and quality. Geological information includes geological cross-sections, drilling and well logs, combined with hydrogeological information to reveal the hydrostratigraphic units of the groundwater basin. Geological cross-sections can reveal geological formations, stratigraphic units, piezometric planes, water chemistry, and formation correlations from drilling logs from several wells. Geoelectrical estimation is a geophysical method for identifying aquifer constituents through aquifer geometry and configuration [17]. Aquifer characteristics are reflected by the parameters and physical properties of the rocks that make up the aquifer. These physical properties include: embankment coefficient, porosity, permeability, and transmissivity. The ability of a water-bearing layer to store and transmit water depends on the thickness and distribution area of the aquifer, porosity, permeability and transmissivity [12].[17].

Hydrostratigraphy of the Aquifer System

The Palu Basin aquifer system is formed by three rock groups: alluvial deposits, clastic sedimentary rocks, and Tertiary-aged compacted rocks. Alluvial deposits are fairly widespread, covering parts of the Palu River valley plain, the Kamamora plain in the upper reaches of the Gumbasa River, and the Walosido plain around Lake Lindu. The thickness of these deposits varies between 60-80 m. They are loose and porous with low to high permeability. The aquifer in these deposits is intergranular. They are widespread and have a transmissivity (T) ranging from 5-250 m/day. Groundwater recharge in the Palu Basin comes primarily from rainfall, with an annual rate of 1,269 mm. Based on the percentage of rainfall, the total recharge in the Palu Basin is estimated at 330 x 106 m/year. shows in Figure 3.

Clastic sedimentary rocks are distributed in several locations, the largest being in the Palu River valley and the hillsides east of Lake Lindu. Stratigraphically, they are located beneath alluvial deposits. They are composed of sandstone, shale, conglomerate, and volcanic rocks. The thickness of these clastic sedimentary rocks is estimated to be quite thick, especially in the Palu River valley, reaching >200 meters. The condition of these rocks is generally loose to somewhat cohesive with low to moderate gradation. The aquifer type in these rocks consists of intergranular spaces, limited to fractures or fissures. The T value of this aquifer type, based on test results, ranges from 10-200 m2/day. The cohesive rocks in the Palu Groundwater Basin are generally older, namely Tertiary rocks. This rock group covers approximately 85% of the Palu Groundwater Basin area. The lithology consists of slate, phyllite, argillite, limestone, siltstone, schist, and genes.

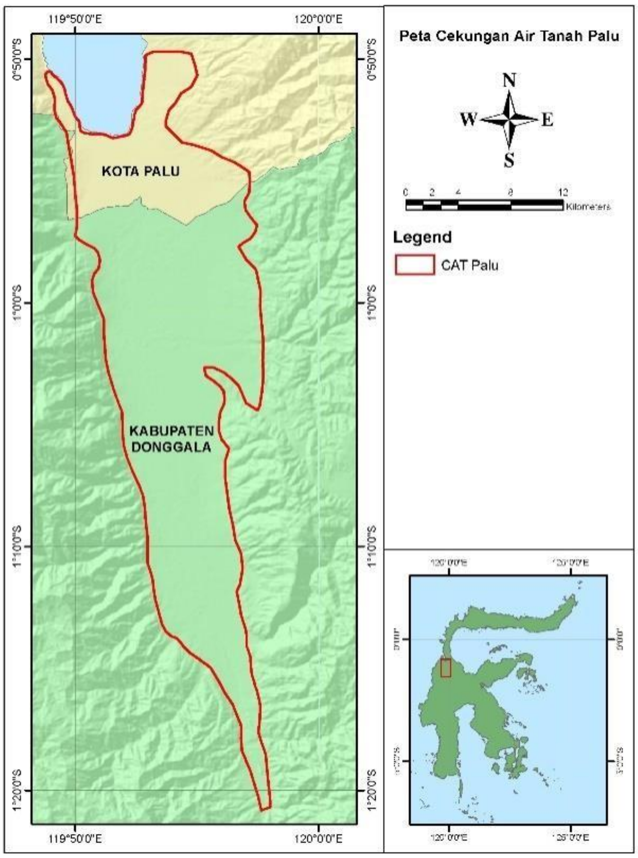

Figure 3: Palu Basin Groundwater Research Location

Based on the conditions of confined and unconfined aquifers, the Palu Groundwater Basin is divided into three aquifer groups: those with well discharge >10 liters/second, those with 2-10 liters/second, and those with <2 liters/second.

1. Aquifers with well discharge >10 liters/second occupy the Palu Basin, distributed across the areas of Kamonji, Donggala Kodi, Balaroa, Duyu, Marawola, Lolu, Tatura, Birobuli, and Sidondo.
2. Aquifers with well discharge of 2-10 liters/second occupy the hillsides flanking the Palu Basin, distributed from the north in the areas of Dalaka, Wani, Tondo, Petobo, and Biromaru to the south in the Saluki area. All of these areas are located east of the fault and south of Sidondo. In the western foothills, the distribution area extends from the south of Donggala, Dondo, Rilantanta, Donggala Kodi, Balaroa, Duyu, Pengawu, Sibedi, to Binangga.
3. Aquifers with well discharges of <2 liters/second occupy the foothills to the summit. In the west, they extend from the area around Donggala and the summit of Mount Gawalise, continuing to Bangga and Kulawi. In the east, they extend from Dolaka, Wani, Pakuli, and Kulawi.

Aquifer System Geometric Configuration

The aquifer system configuration includes determining the lateral and vertical distribution of aquifers and non-aquifers with relatively similar hydraulic characteristics and grouped into a single aquifer system. The aquifer configuration can be determined from the hydrogeological cross-section and the determination of the upper and lower depths of the aquifer system. The upper depth of the confined aquifer significantly determines the optimum discharge (Qopt). The upper depth of the confined aquifer was analyzed based on pumping test data from the Groundwater Utilization and Raw Water Development Department of the Central Sulawesi Province Public Works Agency (2000). Drilling data at the Palu CAT (Groundwater Basin) totaled 78 wells, of which only 23 wells had pumping test data: 5 exploration wells (SE) and 18 production wells (SD). Based on the data analysis, the upper depth of the confined aquifer in the eastern groundwater basin averaged 36.00 meters, while in the western basin it averaged 37.50 meters. The depth of the upper limit of this confined aquifer is in the medium class (20.00 – 50.00 meters). The configuration of the aquifer system to determine the vertical discharge of the aquifer based on the hydrogeological cross-section is sourced from the Directorate of Geology and Environmental Management, 1994.

Alluvial Plain Aquifer System. This aquifer system is a potential primary aquifer, composed of coarse sand, fine sand, and clay. This aquifer system is dominated by an unconfined aquifer with a thickness of >83.24 m. Based on geomorphological conditions, it covers almost the entire Palu CAT area. Groundwater flows continuously from the east (the slope bend of the structural hills of Mount Tanggungguno) and west (the slope bend of the structural hills of Mount Gawalise) towards the alluvial plain along the Palu River. **Denudational Hill Aquifer System**. This aquifer system is also local, located on the eastern and western edges of the alluvial plain. In the west, this aquifer system lies between the alluvial plain aquifer system and the structural hills of Mount Gawalise, extending south to the Bangga area. In the east, this aquifer system lies between the structural hills of Mount Tanggungguno, extending south to the Pakuli area. This aquifer system has a thickness of <83.24 m

The boundaries of the Palu Groundwater Basin were determined by identifying the type of groundwater basin boundary, namely the hydraulic boundary controlled by geological and hydrogeological conditions. The lateral geometry of the Palu Groundwater Basin can be explained as follows, shows in Figure 4.

1. The external zero-flow boundary is the contact area between the aquifer and the non-aquifer that forms the Palu Groundwater Basin. This boundary consists of a fault plane, a conformity, and an unconformity, representing the primary geological structure, dominated by a graben structure known as the Palu Fault.
2. The boundary of the Palu Groundwater Basin, based on the groundwater divide, coincides with the surface water boundary in the main aquifer, separating two opposing groundwater flows.
3. The external head-controlled boundary in the Palu Groundwater Basin is sea level because the main aquifer is unconfined.
4. The inflow boundary of the groundwater is located to the east and west of the Palu River, at the slope bend of the structural hills of Mount Gawalise and Mount Tanggungguno. To the south, at the headwaters of the Palu River in the Kamamora area. The outflow boundary is to the north, at Palu Bay.

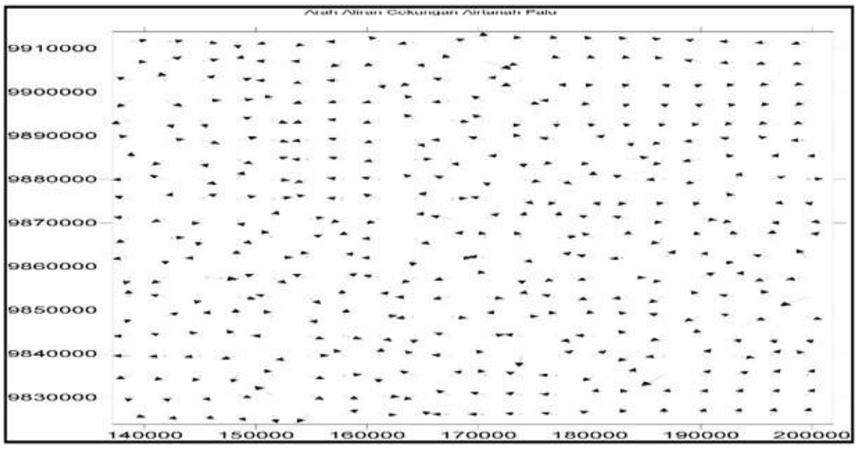

Figure 4: Unconfined Groundwater Flow Direction Model in CAT Palu

Figure 5 and 6 shows the distribution of phreatic surface depths in the Palu CAT, which ranges from moderate (2.5 – 7.0 meters dpt) to shallow (<2.5 meters dpt). The shallowest phreatic surface distribution (1.38 meters dpt) is in West Palu District, while the moderate phreatic surface (2.70 meters dpt) is only found in Gumbasa District. Thus, it can be concluded that the free surface boundary is the boundary of the Palu CAT.

Figure 5: Distribution of Phreatic Level in the Palu Groundwater Basin

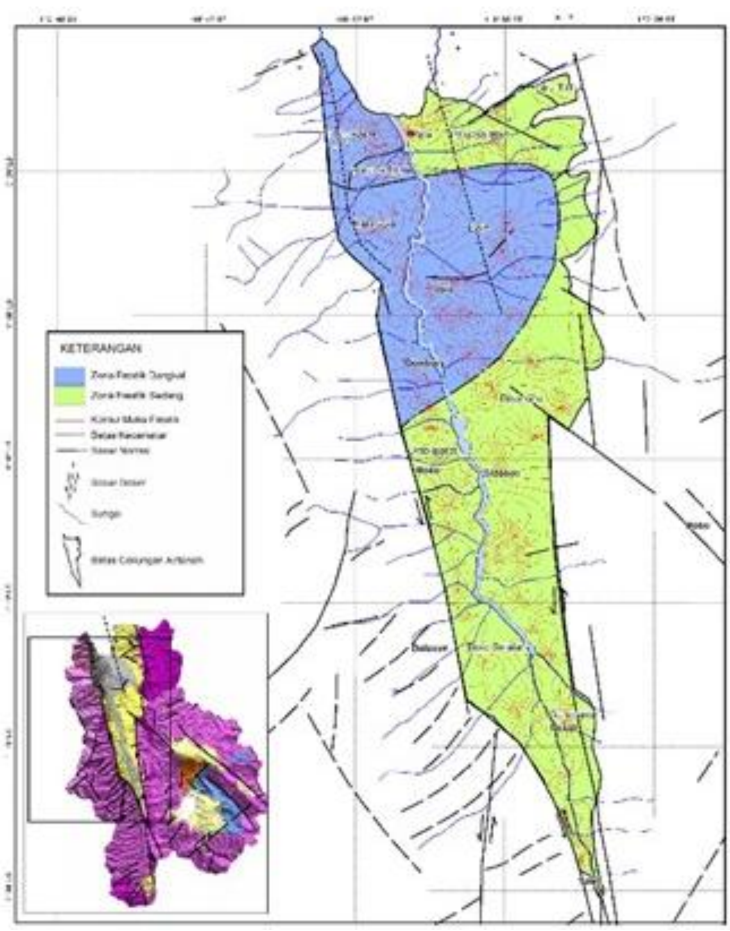

Figure 6: Distribution of Phreatic Level in the Palu Groundwater Basin

III. CONCLUSION

Based on the research results, the following conclusions can be drawn:

1. Geometrically, the boundaries of the Palu Groundwater Basin were determined by identifying the type of groundwater basin boundary, namely the hydraulic boundary controlled by geological and hydrogeological conditions.
2. The spatial distribution of the aquifer system, based on an integrated geomorphological and geological approach, indicates that the lateral distribution of the aquifer is determined by geomorphological conditions and the vertical distribution by geological conditions.
3. Hydrostratigraphically, the Palu Basin serves as a boundary separating surface water flow, or the boundary of the Palu Watershed. Geomorphologically, it represents the lateral boundary of the basin and geologically, it represents the vertical boundary of groundwater flow (flow-controlled boundaries), along the slopes of the structural hills of Mount Gawalise in the west and Mount Tanggungguno in the east of the Palu Basin.

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REFERENCES

[1]. Didiek D 2019 Geotechnical Report on 2018 Palu-Donggala Earthquake *PUSGEN*
[2]. Risna Widyaningrum 2012 Laporan Penelitian Geologi.
[3]. H.Th, Verstappen 1983 Applied geomorphology. Geomorphological surveys for environmental development *Elsevier*
[4]. Derry Prasetya Putra Santosa, Mohamad Sapari Dwi Hadian, Zulfialdi Zakaria. 2021. *Jurnal Sumber Daya Air. 17 01*
[5]. Zeffitni 2010 Disertation (Gadjah Mada University)
[6]. Derbyshire E, Gregory K J and Hails J R 1979 *Geomorphological Processes* (Elsevier) pp 44–106
[7]. Boehmer W K and Boonstra J 1987 *Journal of Hydrology* **94** 199–214
[8]. Cheng Z, Su C, Zheng Z, Chen Z and Wei W 2021 *Journal of Hydrology* **603**
[9]. Sedghi M M and Zhan H 2021 *Journal of Hydrology* 127030

[10]. Zeffitni -, Basir-Cyio M and Napitupulu M 2019 *Int. J. Adv. Sci. Eng. Inf. Technol* **9** 1725
[11]. Ninasafitri and Zeffitni 2021 *J. Phys.: Conf. Ser.* **1763** 012088
[12]. Verstappen H Th 1978 *Earth-Science Reviews* **14** 71
[13]. Zeffitni 2021 *J. Phys.: Conf. Ser.* **1763** 012087
[14]. Kresic Neven 2010 *Hydrology of Springs* (Elsevier) pp 1–29
[15]. Zeffitni 2012 J*urnal Manusia dan Lingkungan*. 06 1
[16]. Mutua S, Ghysels G, Anibas C, Obando J, Verbeiren B, Van Griensven A, Vaessens A and Huysmans M 2020 *Journal of Hydrology: Regional Studies* **32** 100766
[17]. Zeffitni, Basir-Cyio M, Napitupulu M and Worosuprojo S 2020 *J. Phys.: Conf. Ser.***1434** 012019