# Delineation of Groundwater Density Zones Using Multi-Criteria Analysis in Ngatabaru Village Area, Palu City

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ABSTRACT

**Introduction:** This research discusses the availability of groundwater in the Ngatabaru Village area. The use of groundwater, which tends to be more intensive and is not in accordance with its availability and utilization zone, ultimately has an impact on the local environment. **Method:** This study used the overlay method to determine the groundwater conditions in the study area. This method uses 7 parameters to determine the groundwater zone, namely lithology, hydrogeology, land cover, rainfall, slope, drainage density, and lineament density. **Results and Discussion:** This map produces 5 groundwater occurrence zones which show that 34.32% of the study site is an area with very low groundwater occurrence, then 37.19% is an area with low groundwater occurrence, 9.08% is an area with moderate groundwater occurrence, 12.91% is an area with high groundwater occurrence and 6.5% is an area with very high groundwater occurrence. **Conclusion:** Based on the analysis, Kelurahan Ngatabaru has low annual rainfall, ranging from 0 to 800 mm. The slope is steep in the east and slopes to the west, with forest land cover in the east and scrub and settlements in the west. Geologically, the area consists of schist, granite, and conglomerate lithologies, and has aquifers with high, low, and little productivity.



## 1. Introduction

Water is a basic human need for survival. *Groundwater* is water that occupies cavities in geological layers in a saturated state and in sufficient quantities (identical to aquifers). Groundwater is one of the sources of water needed for the life of creatures on earth. The use of groundwater which tends to be more intensive and not in accordance with the availability and utilization zone ultimately has an impact on the local environment [1]. Based on Governor Regulation Number 10 of 2019 concerning the relocation of residential areas affected by the earthquake, tsunami, and liquefaction disasters in the Palu City area. So 4 (four) locations are proposed for post-disaster settlement relocation [2].

Ngatabaru Village is one of the relocation locations for the relocation of Palu City settlements. This relocation will have an impact on the need for land for settlements and will also have an impacton the increasing demand for clean water resources. Surface water is strongly influenced by weather conditions where in the dry season the supply of surface water will be reduced. This condition triggers increased groundwater utilization.

Administratively, the study area is included in Ngatabaru Village, Sigi Biromaru Subdistrict, Palu City, Central Sulawesi, with a total area of 3,118 ha. The research area is included in the RBI (Rupa Bumi Indonesia) scale 1:50,000 Palu Sheet Number 2015- 32 published by the Geospatial Information Agency in 1991. The distance from the center of Palu City to the research location is approximately 15 km and the travel time is about ± 30 minutes by using land

transportation in the form of cars and motorcycles. One of the six biogeochemical cycles that occur on Earth is the hydrological cycle, which is the circulation or flow of water from Earth to the atmosphere and back to Earth. This cycle is continuous. In reality, water passes through more than one stage in this hydrological cycle, The hydrological cycle consists of many processes, including evaporation, transpiration, evapotranspiration, sublimation, condensation, advection, precipitation, runoff, and infiltration.

Groundwater is water contained in layers of soil or rock below the ground surface and is dynamic so that the availability of groundwater is certainly related to the geological conditions of an area, where there are various factors that have an influence and can control the distribution and availability of groundwater. Based on previous research, there are several parameters that are assumed and believed to have an important role as controlling factors for groundwater availability, these factors include lithological conditions, slope, rainfall, land cover, drainage density, and straightness structure density. Thus, by conducting a multi-criteria weighting analysis on existing parameters with a GIS approach, it is possible to map the distribution of groundwater levels in an area

## 2. Reserch Method

The research method used in this study was carried out qualitatively. The qualitative method is carried out by collecting data in the form of existing maps and field surveys that produce maps in the form of lithology maps, hydrogeology maps, slope maps, alignment density maps, *drainage* density maps, cover maps, and rainfall maps. Then, multi-criteria analysis and *overlay were* conducted to produce a map of groundwater availability zones in the research area.

Regionally the study area consists of Metamorphic Complex (Km), Tinombo Formation (Tt), Molasa Celebes land Sarasin/ (QTms), Alluvium and Coastal Deposits (Qap), and Intrusive Rocks (gr) [3]. Below will be described from old to young formations at the research location.

a) Metamorphic Complex (km)

The metamorphic rock complex consists of amphibolite schist, schist, genes, and marble. The schists are abundant on the west side, while the genes and marble are abundant on the east side. The intrusive bodies are unmappable, generally less than 50 meters wide, breaking through the metamorphic rock complex, with rock types ranging from diorite to granodiorite. The age of metamorphism is unknown, but probably pre-Tertiary.

b) Tinombo Ahlburg Formation (Tt)

The Tinombo Formation sequence is widely exposed in both the eastern and western mountain ranges overlying a complex of metamorphic rocks. It consists mainly of shale, sandstone, conglomerate, limestone, radiolaria, and volcanic rocks, deposited in a marine environment. In areas near the intrusion, there is slate while those closer to the contact form phyllite and quartzite. The western part of the western mountain range contains more Rijang sandstones than elsewhere.

Diabase, phyllite, and andesite in southern Donggala and in southern Kasimbar are mapped with sedimentary rocks. Remnants of volcanic rocks are commonly found in sandstones while limestones are found only as thin layers and small intrusions are also found in this formation. Based on the fossils present in this formation

such as *Discocyclina sp., Nummulites sp., Alveolina sp., Miliolidae, Asterocyclina sp., Assilina sp., Operculina sp., Globorotaloid, Globigerina* and algae beds, may indicate that the formation is Eocene in age. Meanwhile, fossils found by SOCAL (Standard Oil Company of California) found fossils such as *Pellastipira., cf. P. infata, cf. Pararotalia sp., Eofabiana, Pellatispira crassicolumnata., Sphaerogypsina sp., Rotalia sp.*, and *Carpenteria hamiltonensis* indicate that this formation is Middle to Upper Eocene in age [3].

c) Intrusive Rocks (gr)

The formation is characterized by the presence of small andesite and basalt intrusions on the Donggala peninsula, which are the oldest intrusions. These intrusions are likely the result of activity from volcanic rocks within the Tinombo Formation. Small intrusions less than 50 metres wide consisting mainly of diorite, diorite porphyry, and microdiorite break through the Tinombo Formation and are widespread throughout the area. granite and granodiorite that have been mapped, characterized by potassium feldspar phenocrysts up to 8 cm long. Potassium/Argon dating has been carried out by Gulf Oil Company on two granodiorite samples from this area. Intrusions exposed between Palu and Donggala give a date of 31 million years ago on K/Ar analysis of the feldspars [3].

d) Molasa Celebes Sarasin (QTms)

This formation overlies the Tinombo Formation and the Metamorphic Complex, then this formation also contains debris derived from older formations, and consists of Conglomerate, Sandstone, Mudstone, Limestone, Coral, and Napal which are all only weakly hardened. Near Donggala to the north of Enu and west of Labean, the rocks consist mainly of Limestone and Napal containing *Operculina sp.*, *Cycloclypeus sp*., *Rotalia sp.*, *Orbulins Universa*., *Amphistegina sp.*, *Miliolidae*, *Globigerina*, passive foraminifera, Limestone algae, *pelesipods* and *gastropods.* A sample collected from Southeast Laebago in addition to these fossils also contained *Miogysina sp*, and *Lepidocylina sp*, indicating a Miocene age. Additional forams recognized by SOCAL include *Planorbulina sp*, *Solenomeris sp*, *Textularia sp*, *Siroclypeus sp*, *Lethoporella*, and *Amphiroa*, where the fossils indicate a Middle Miocene age with a depositional environment in shallow water. Later Quaternary river deposits found on both sides of Palu Bay, and possibly elsewhere are included in this unit.

## 3. Results and Discussion

Based on the research that has been carried out to determine the groundwater density zone, it is necessary to know the parameters that affect it, namely Geology, Hydrogeology, Slope, Land Cover, Rainfall, Drainage Density, and Straightness Density.

The groundwater zone map is made based on the results of *a weighted overlay* analysis of 7 (seven) parameters consisting of lithology, hydrogeology, land cover, rainfall, slope, drainage density, and straightness density (Figure 1). As for the determination of the score and weight values, I used the reference/journal classification [4].

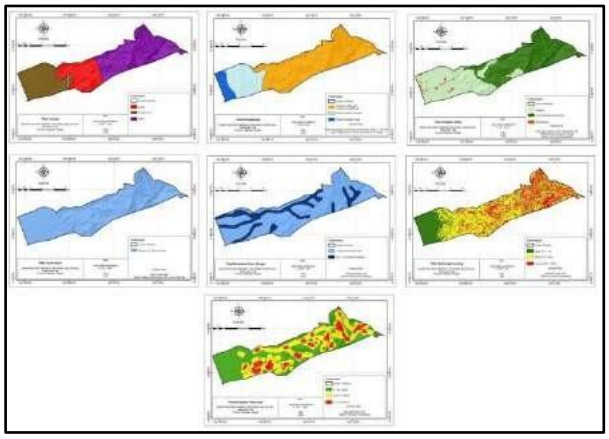

**Fig. 1.** Parameters for determining the groundwater zone in Ngatabaru Village.

In the feasibility analysis of aspects in the assessment of groundwater occurrence zones. For the determining component, a value is given to determine the influence of each class on the

determination of the groundwater zone. Table 1 shows the ranking or value of each parameter that affects the groundwater zone in Ngatabaru Village, Palu City.

Table 1. Assessment data of groundwater occurrence parameters of Ngatabaru urban village

| | No | Criteria | Category | Score | Weight |
|---|---|---|---|---|---|
| 1 | 1 | Lithology | Conglomerate Unit | 2 | 0.135 |
| 2 | 1 | Lithology | Granite Unit | 1 | 0.135 |
| 3 | 1 | Lithology | Schist Unit | 1 | 0.135 |
| 4 | 2 | Hydrogeology | High productivity aquifer | 2 | 0.359 |
| 5 | 2 | Hydrogeology | Low productivity aquifer and rare groundwater | 1 | 0.359 |
| 6 | 3 | Slope Gradient (%) | Flat (0% - 7%) | 3 | 0.204 |
| 7 | 3 | Slope Gradient (%) | Moderate (7% - 30%) | 2 | 0.204 |
| 8 | 3 | Slope Gradient (%) | Steep (30% - 140%) | 1 | 0.204 |
| 9 | 4 | Land Cover | Forest | 2 | 0.068 |
| 10 | 4 | Land Cover | Shrubs | 1 | 0.068 |
| 11 | 4 | Land Cover | Settlement | 3 | 0.068 |
| 12 | 5 | Rainfall | 0 - 800 mm/year | 2 | 0.146 |
| 13 | 6 | Drainage Density | 151 - 422 m | 1 | 0.04 |
| 14 | 7 | Lineament Density | 0 - 3.8 /km$^2$ | 2 | 0.048 |
| 15 | 7 | Lineament Density | 3.8 - 9.7 /km$^2$ | 1 | 0.048 |
| 16 | 7 | Lineament Density | 9.7 - 25 /km$^2$ | 3 | 0.048 |

Based on the results of the overlay of each parameter that has been given a score and weight, the groundwater density zone is divided into 5 classes, namely very low, low, medium, high, and very high.

Based on the resulting map of the groundwater density zone of Kelurahan Ngatabaru, it can be seen that most of the research locations are dominated by very low -very low groundwater density zones where the very low zone has a percentage of 34.32% of the total research location and a low zone of 37.19% of the total research site, then there is also a medium density zone with a distribution area covering 9.08% of the total research site, then only a small portion is left for zones with high and very high groundwater density levels in the research site where the high-density zone has a percentage area of 12.91% and for a very high-density zone of 6.5%. The area and zone of groundwater density at the research location can be seen in Table 2.

Table 2. Distribution of groundwater zone classes in Ngatabaru urban village, Palu city

| | Class | Criteria | Area (Ha) | Percentage (%) |
|---|---|---|---|---|
| 1 | 1 | Very Low | 1070.25 | 34.32 |
| 2 | 2 | Low | 1160.01 | 37.19 |
| 3 | 3 | Moderate | 283.21 | 9.08 |
| 4 | 4 | High | 402.7 | 12.91 |
| 5 | 5 | Very High | 202.66 | 6.5 |

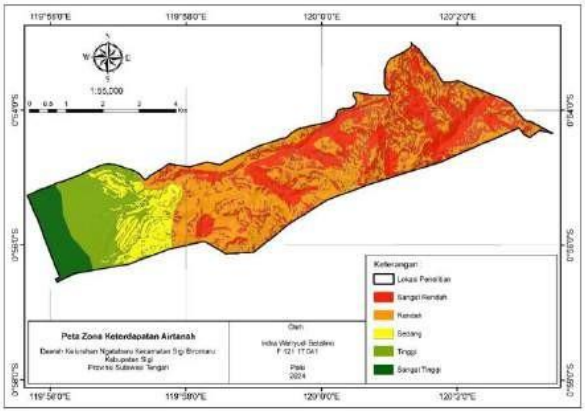


**Fig. 2.** Groundwater occurrence zone of Ngatabaru urban village, Palu city

Descriptively the division of groundwater availability zones in the Tondo urban village is as follows (Figure 2):

a) The zone with a very low groundwater level is a zone spread in the central-eastern part of the research area with an area of 1070.25 Ha [5]. This zone as a whole is an area composed of steep slope classes, so this zone is an area with a small *inflation* rate, this is because on steep slopes there will be more frequent surface flow. Then in this zone, is also composed of a schist unit rock which is a metamorphic rock that has an epiblastic structure, and a granite unit which is an igneous rock that has a massive structure, where both types of rocks have secondary permeability types and aquifer types, aquifer, and aquitard so that both types of rocks have a small infiltration rate. And the characteristics of both rocks are *impermeable*, then based on the hydrogeological map this zone is also included in the rare groundwater area and also a small productive aquifer.

b) The zone with a low level of groundwater is a zone with an area of 1160.01Ha and is spread starting from the center - the eastern end of the research location. This zone as a whole is an area with a sloping slope level, so this zone is classified as an area with a poor level of water *infiltration, this* is because on a sloping slope class, the surface flow process will be more dominant than the water *infiltration process* [6]. Then in this zone, is also composed

of schist rock units which are metamorphic rocks that have a Lepidoblastic structure, and granite units which are igneous rocks that have a massive structure, where both types of rocks have poor permeability types (secondary) and aquifer types, aquifer, and aquitard so that both types of rocks have a small infiltration rate. The characteristics of both rocks are *impermeable*, while in the hydrogeological map, this zone is also included in the small productive aquifer area.

c) The zone with a medium groundwater level is a zone spread over an area of 283.21 Ha and is located in the western part of the research site, then based on the hydrogeological map this zone is included in an area with low productive aquifer conditions. Then when looking at the lithologic conditions, this zone is composed of conglomerate units consisting of sandstones, where the rocks have a layered structure and have aquiclude and aquitard aquifer types. These rocks are also characterized by rocks with good *porosity* and *permeability* (primary) to store and drain water. This zone is also composed of a gentle to sloping slope class so that the *infiltration* process can take place quite well, then this zone is also composed of land cover types of settlements and shrubs.

The zone with a high groundwater level is a zone spread over an area of 402.7 Ha in the western part of the study area, this area has a gentle slope condition with land cover types in the form of shrubs and settlements. Based on the type of rock, this zone is composed of conglomerate units consisting of sandstones, where the rocks have a layered structure and have aquiclude and aquitard aquifer types. These rocks are also characterized by rocks with good *porosity* and *permeability* (primary) to store and drain water. Based on the hydrogeological map, this zone is also included in an area with low productive - high productive aquifer conditions so that based on these main factors this zone can become a zone with a high level of Groundwater.

d) The zone with a very high groundwater level is a zone spread over an area of 202.66 Ha in the western part of the study area, this area has a gentle slope condition and also a lithology type in the form of a conglomerate rock unit consisting of sandstones, where the rock has a layered structure and has an aquifer type of aquiclude and aquitard. These rocks also have rock characteristics with good *porosity* and *permeability* (primary) to store and drain water. then based on the hydrogeology map this zone is included in an area with highly productive aquifer conditions so that based on several main factors this zone can become a zone with a very high groundwater level.

## 4. Conclusion

Based on the results of the analysis and discussion, it can be concluded that the Ngatabaru Village area is an area with a low average level of annual rainfall, where the rainfall ranges between 0 - 800 mm/year. Then based on the slope conditions, the eastern part of the Ngatabaru Village area has steep slope conditions and begins to slope towards the west, has a type of land cover in the form of forests in the east and shrubs and settlements in the west. Based on rock conditions and hydrogeology, the Ngatabaru Village area is composed of schist lithological units, granite units, units, and Conglomerate. with aquifer types in the form of high-productive aquifers, low-productive aquifers, and small productive aquifers. Ngatabaru Village area also has a low density of river flow (151 - 422m) Average (283.44m), The density level of straightness structure in the study area is dominated by a low-density level (0 - 0.38 m/$Km^2$ ) which is then followed by a medium density level (0.38 - 9.7 m/$Km^2$ ), and a high-density level (9.7 - 25 m/$Km^2$ ). Based on the groundwater density zone map made, it is known that there are 5 (five) classes of groundwater density levels in the Ngatabaru urban village area, where 34.32% of the research location is an area with a very low level of groundwater density, then 37.19% is an area with a low level of groundwater density, 9.08% is an area with a medium level of groundwater density, 12.91% is an area with a high level of groundwater density and 6.5% is an area with a very high level of groundwater density.

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