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GROUNDWATER FLOW PATTERN AROUND GONOHARJO HOT SPRING, KENDAL REGENCY, CENTRAL JAVA

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Abstract— The Ungaran Mountain is a stratovolcano-type volcano with a geothermal system. On the northern side of Mount Ungaran, there are hot springs located in the Gonoharjo area, Kendal Regency, Central Java, Indonesia. These hot springs appear on the mountain slopes and are very close to the surface water. This research aims in analyzing the pattern of groundwater flow with surface water flow around the springs and identifying the relationship that occurs between the springs and the nearest river flow. Analysis of the groundwater flow pattern can be determined based on groundwater level contour maps and groundwater flow maps. Such mapping can occur by plotting groundwater level data measured from 16 springs scattered on the slopes of Mount Ungaran. As a result of the measurements taken, the groundwater level ranged from 298.02 m above sea level to 818.47 m above sea level. The highest groundwater level is in the Pakis area while the lowest groundwater level is in the Boja area. The groundwater flow pattern at the study site flows from the top of the mountain and spreads to the north, northwest, west, southwest. Based on the 15 cross sections conducted, it can be identified that in general the relationship between groundwater and rivers flow in the study area is that most of the groundwater supplies surface water.

Keywords—Gonoharjom, groundwater, flow pattern, rivers flow, hot springs

I. INTRODUCTION

Central Java Province is known to have several mountains that are still active dorman. One of them is Mount Ungaran which is located in Semarang Regency, Central Java. Mount Ungaran is a geothermal system stratovolcano type that has a thermal energy source in the form of Fumarole, hot soil, travertine deposits, hot springs and literate rocks that show underground geothermal activity.[1] On the north side of Mount Ungaran, namely on the slopes of the mountain in the Nglimut area, Gonoharjo Village shows geothermal reserves that appear to the surface in the form of hot springs. On the slopes of Mount Ungaran, there are also several springs, either those that appear directly or need drilling to extract groundwater. Groundwater is a source of water that is physically of better quality than surface water or rivers, but environmental conditions also affect the quality of groundwater itself.[2]

In general, groundwater hydrology has a direct relationship with river flow. The relationship that occurs is losing stream and gaining stream which can be determined based on the position of the groundwater table compared to the location of the river water table. Losing stream is a condition that occurs when the location of surface water is higher so that surface water can provide water supply to the ground, while gaining stream occurs because the position of the groundwater level is more than the position of the river water table so that river water will receive water supply from the flowing ground.[3]

The direction of groundwater flow can be determined based on groundwater level data from several adjacent springs or wells.[4] The purpose of meeting groundwater flow patterns is to show the direction of soil flow from where and to where the flow is and show the interaction that will occur between groundwater and surface water at the study site based on water level data.

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Groundwater is water derived from surface water that moves into soil cavities.[5] Another definition of groundwater itself is water that is below the ground surface and is located in the zone of saturation. The emergence of groundwater itself comes from surface water and rainwater and then seeps (Infiltration) from initially entering the unsaturated water zone then seeps deeper and deeper until it enters the saturated water zone so that it collects into natural reservoirs or aquifers then groundwater is formed. Groundwater can be reused to the ground surface as a source of spring water and can also be reflowed through dug wells or boreholes, therefore groundwater is also part of the hydrological system.[4]

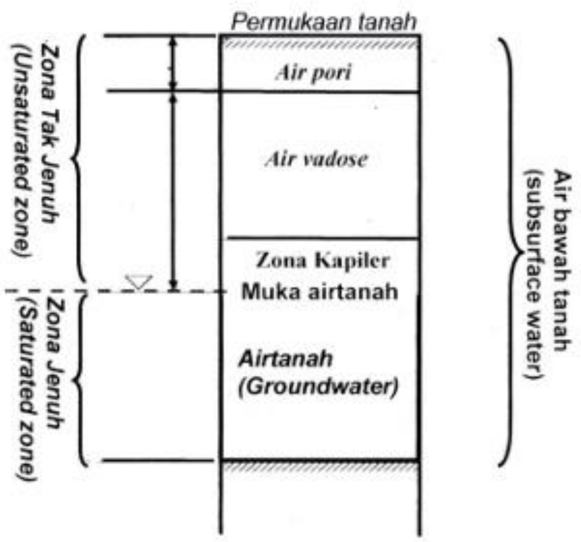

Figure 1 Groundwater Zone[4]

II. METHODS

The research was conducted in Limbangan District and its surroundings, precisely on the north slope of Mount Ungaran, Central Java and obtained 16 points of spring sources as shown in Figure 3.1 is a Map of the Distribution of Spring Source Location in the Research Area. The groundwater table can be measured by calculating the difference between the height of the land surface and the depth of the groundwater table with the following equation:[6]

$$EL.MAT = EL.MT + h - SWL$$

With

EL. MAT	= Elevation of Groundwater,
EL. MT	= land surface elevation
h	= Height of the well lip (m),
SWL	= Dept of well water level (m)

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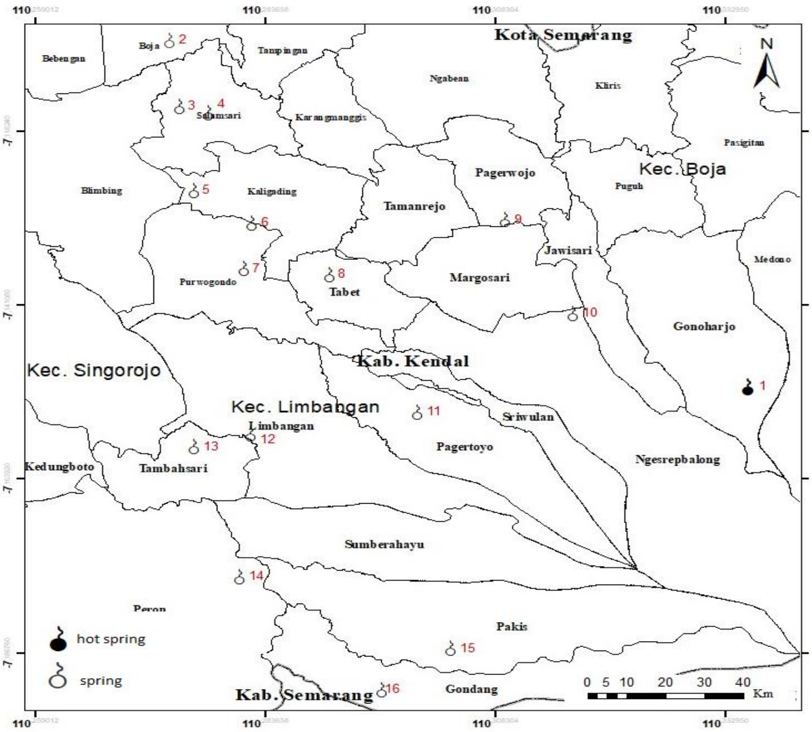

Figure 2 Map of Spring Distribution

III. RESULT AND DISCUSSION

Based on the results of the data acquisition that has been carried out, 16 points of spring water sources are divided into several areas of Limbangan District and Boja District.

Table 1 Groundwater Level Values

District	Well Point	MAT (m)	Elevation (mdpl)	Coordinate	
				x	y
Nglimut	1	809,66	810	110,335334	-7,151664
Boja	2	298,02	304,42	110,273331	-7,106308
Salamsari 1	3	312,59	323	110,274327	-7,11503
Salamsari 2	4	320,95	328,5	110,277488	-7,115873
Kaligade 1	5	368,16	373,5	110,27585	-7,125992
Kaligade 2	6	382,46	384,8	110,282127	-7,130235
Purwogondo	7	392,58	395,8	110,281263	-7,136285
Tabet	8	427,58	432,7	110,290413	-7,137057
Pagerwojo	9	473,15	474	110,309271	-7,129852

Margosari	10	614,39	615,15	110,316546	-7,14216
Pagertoyo	11	544,26	545,5	110,299861	-7,155003
Limbangan	12	487,72	493,12	110,282022	-7,157935
Tambahsari	13	490,64	497,8	110,275887	-7,159585
Peron	14	539,44	545,5	110,280777	-7,176695
Pakis	15	818,47	819,37	110,303455	-7,186042
Godang	16	723,5	724	110,29599	-7,191422

The results of data acquisition obtained as many as 16 well points and springs located in the research area shown in **Table 1** Furthermore, by plotting coordinate points and connected with the position of the groundwater table at each point. Then the results of the plotting will be obtained a contour map of the groundwater table using ArcGIS software shown in **Figure 3** as a contour map of the groundwater table.

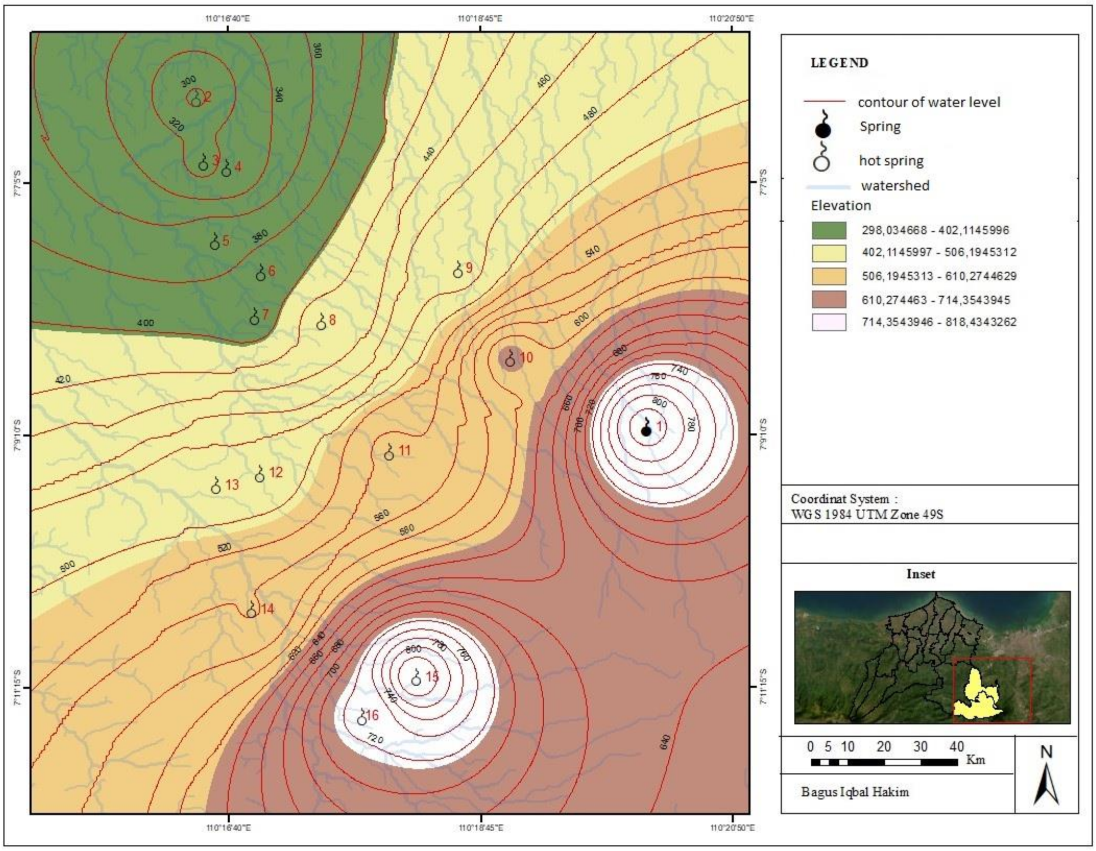

Figure 3 Groundwater Level Contour Map

The moving groundwater flow pattern will be determined by the contour of the groundwater table. Groundwater flow patterns can be depicted by drawing a perpendicular line intersecting the contour of groundwater from a higher elevation to a lower elevation due to the influence of gravitational potential.[7] **Figure 4** shows a map groundwater flow patterns.

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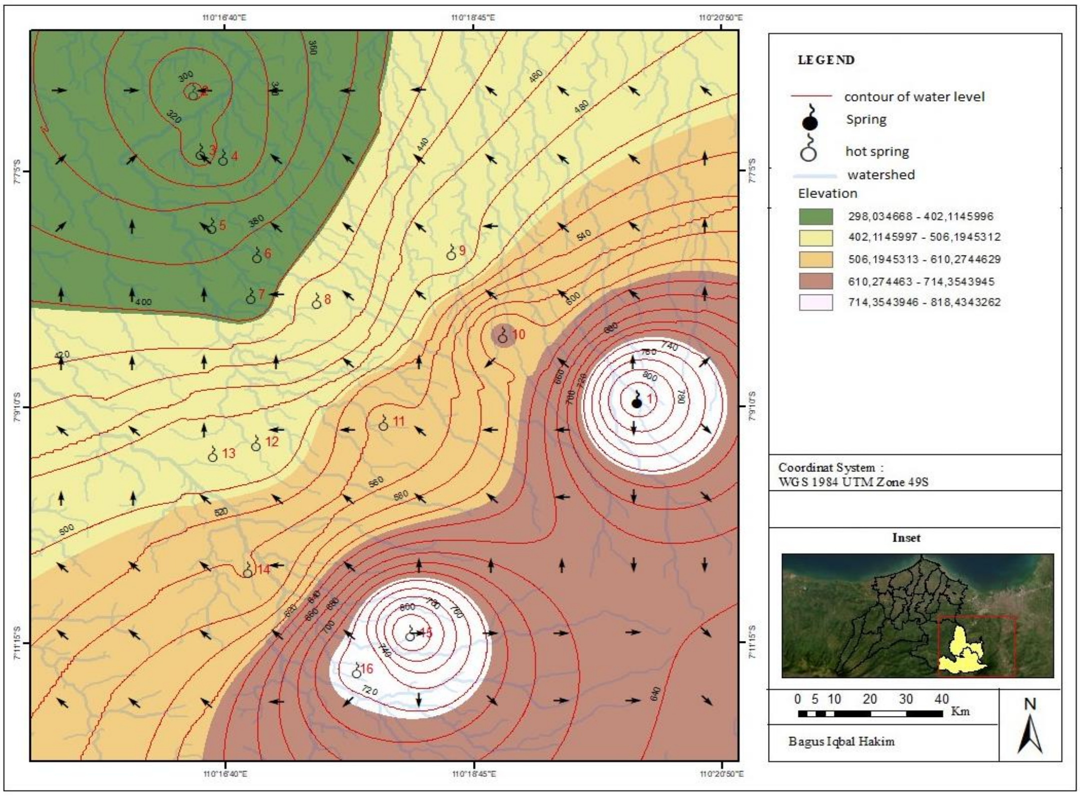

Figure 4 Groundwater Flow Pattern Map

Based on **Figure 4**, you can see the pattern of groundwater flow flowing from the slopes of Mount Ungaran to areas that have low elevation. This is in accordance with the assumption that groundwater will always move due to the gravitational force of the contour of the groundwater table which has a higher altitude to a lower altitude.

Figure 5 shows the results of simulated surface water flow patterns using ArcGIS software. It is based on the topography of the southern slopes of Mount Ungaran. The map shows the surface water flow pattern draining from the higher topography to the lower topography. Meanwhile, groundwater flow is shown by a perpendicular line that intersects the contours of the groundwater level.

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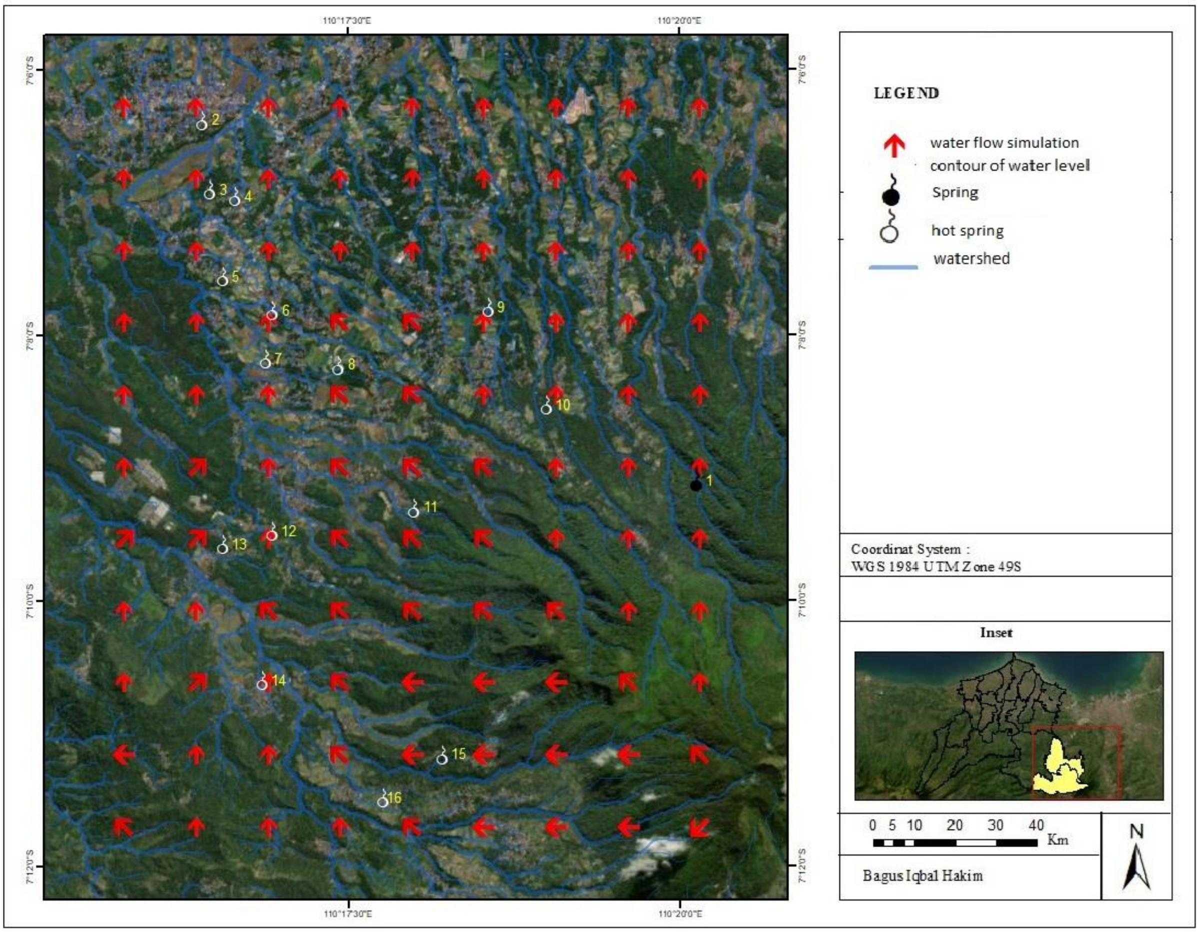

Figure 5 Simulation of Surface Water Flow Patterns

It is an interesting study whether the flow pattern of the surface water springs will recharge the hot springs or the hot springs will supply the surface water flow. To see the relationship between the two opportunities, it is shown by first analyzing the results of field measurements (table 2) and drawing a cross-section of each groundwater table in comparison with the height of the surface water flow.

Table 2 River Water Level Values

District	River Point	River Water Level(m)	Coordinate	
			x	y
Nglimut	1	790,8	110,335277	-7,150836
Boja	2	270	110,277577	-7,106896
Salamsari	3	315	110,273919	-7,113942
Kaligade 1	4	350	110,272064	-7,123048
Kaligade 2	5	390,5	110,28383	-7,13097
Purwogondo	6	375,5	110,275758	-7,136653
Tabet	7	453	110,296337	-7,138404
Pagerwojo	8	514,5	110,310037	-7,13528
Margosari	9	562	110,317133	-7,139295

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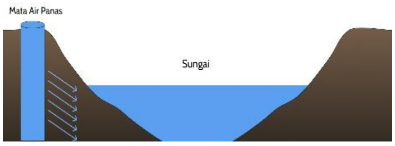
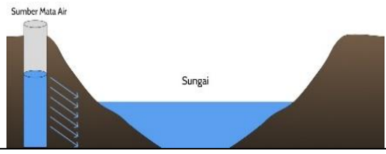
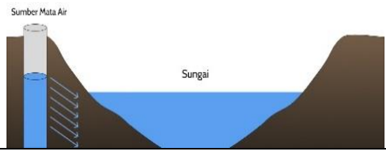
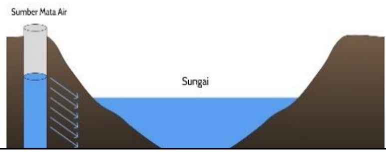
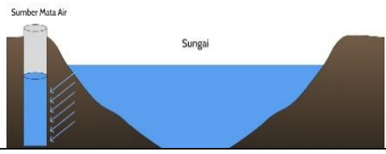
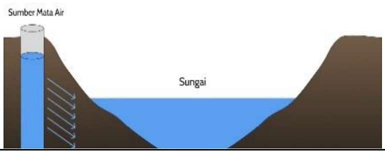
District	River Point	River Water Level(m)	Coordinate	
			x	y
Pagertoyo	10	509	110,297424	-7,15457
Limbangan	11	496	110,282685	-7,159618
Tambahsari	12	457,5	110,272406	-7,163581
Peron	13	509,7	110,283633	-7,17688
Pakis	14	849,4	110,310784	-7,188585
Godang	15	670,4	110,291398	-7,193247

In this study, the relationship between each hot spring and the surface water that flows through it was analyzed by describing the respective water levels in a separate illustration (Table 3). This makes it easy to recognize the water level relationship between the two resources. In accordance with the concept of hydrodynamics, the higher water level will recharge the lower water level.

Table 3 Connection of Spring Sources with River

Cross Section	**Elevation Water Surface**		**Sketch**	**Types of Connection**
	Source Spring	**River**		
1	810,16	790,8		Groundwater Flowing into Rivers (Gaining stream)
2	298,02	270		Groundwater Flowing into Rivers (Gaining stream)
3	320,95	315		Groundwater Flowing into Rivers (Gaining stream)
4	368,16	350		Groundwater Flowing into Rivers (Gaining stream)
5	382,46	390,5		Groundwater Receives Flow from Rivers (Losing stream)
6	392,58	375,5		Groundwater Flowing into Rivers (Gaining stream)

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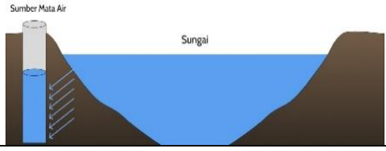
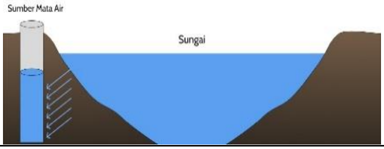
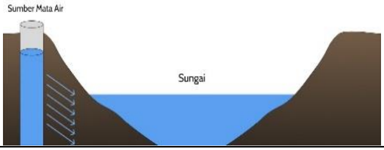
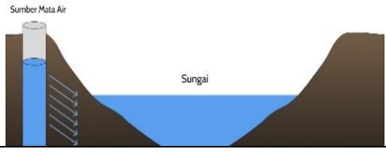
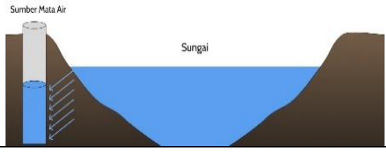
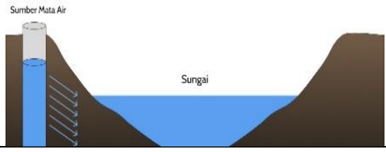
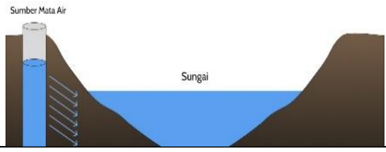
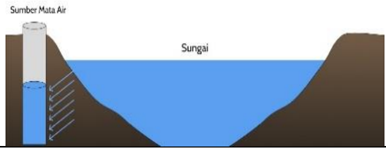
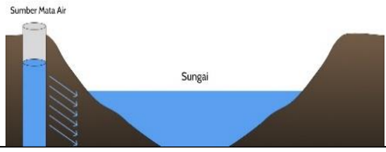
7	427,58	453		Groundwater Receives Flow from Rivers (Losing stream)
8	473,15	514,5		Groundwater Receives Flow from Rivers (Losing stream)
9	614,39	562		Groundwater Flowing into Rivers (Gaining stream)
10	544,26	509		Groundwater Flowing into Rivers (Gaining stream)
11	487,72	496		Groundwater Receives Flow from Rivers (Losing stream)
12	490,64	457,5		Groundwater Flowing into Rivers (Gaining stream)
13	539,44	509,7		Groundwater Flowing into Rivers (Gaining stream)
14	818,47	849,4		Groundwater Receives Flow from Rivers (Losing stream)
15	723,5	670,4		Groundwater Flowing into Rivers (Gaining stream)

Analyzing the cross-sectional sketches (Table 3) of each spring and river in the study area can be categorized into two flow patterns: the groundwater recharges the surface water (gaining stream) as in Nglimut, Boja, Salamsari, Kaligade1, Purwogondo, Margosari, Pagertoyo and Gondang. The next event is the opposite in the form of losing streams in the Kaligade2, Tabet, Pagerwojo, Limbangan and Pakis areas.

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IV. CONCLUSIONS

The relationship between groundwater and surface water or rivers in the research site is groundwater recharging surface water (Gaining Stream) and groundwater receiving surface water (Losing Stream). Areas that have gaining streams are Nglimut, Boja, Salamsari, Kaligade1, Purwogondo, Margosari, Pagertoyo, Tambahsari, Peron, Gondang. Whereas areas experiencing Losing Stream conditions are Kaligade2, Tabet, Pagerwojo, Limbangan, Pakis.

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