Implementation of The AHP Method to Determine the Priority of Recharge Areas in The Semarang City_V3

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IMPLEMENTATION OF THE AHP METHOD TO DETERMINE THE PRIORITY OF RECHARGE AREAS IN THE SEMARANG CITY

Abstract. One of the impacts of the environmental damage is the damage to the potential for groundwater supplies. This environmental damage is caused by changes in land use, especially in areas of groundwater recharge, residential and industrial development as well as uncontrolled pumping of groundwater. If this happens for a long period, it can disrupt the hydrological cycle system which results in decreased quality and quantity of groundwater, flood, erosion and landslides and seawater intrusion. Therefore, the selection of a certain region as an area for groundwater recharge requires priority on the development of a region. Groundwater recharge area has an important role in maintaining a clean water supply in an urban area. The urban area is an area that experiences rapid development, especially changes in land use that have turned into residential and industrial areas. In this discussion, the method of the Analytical Hierarchy Process (AHP) was used to determine the priority scale of the catchment area development in the city of Semarang. The AHP method was used to analyze data that has a variety of dimensions simultaneously so that it is based on the data contained in the variables used in identifying the area. The results of the analysis can produce 10 priority areas for groundwater recharge and their ranking which can be developed gradually as catchment areas in the city of Semarang.
Keyword: AHP method, water recharge area, priority scale, ranking.

Introduction. One of the impacts of the environmental damage is the damage to the potential for groundwater supplies. This environmental damage is caused by changes in land use, especially in areas of groundwater recharge, residential and industrial development as well as uncontrolled pumping of groundwater [1]. If this happens for a long period, it can disrupt the hydrological cycle system which results in decreased quality and quantity of groundwater, flood, erosion and landslides and seawater intrusion. Several studies have been conducted to maintain groundwater supplies, including by building wells and infiltration trenches [1, 2], and groundwater recharge areas [3, 4, 5, 6].

The selection of an area to become a groundwater recharge area has been carried out in previous studies. The methods of the selection can be grouped into three. The first method is by using analysis on geospatial data [3, 5, 7, 19, 20]. The second one is by using Analytical Hierarchy Process (AHP) [2, 4, 8].

The third is by involving artificial intelligence methods [9, 10]. Application of AHP has special characteristics as compared with the other two methods which are the results are not only the selection of an area as a groundwater recharge area but also simultaneously show the order of priority of the areas were classified as eligible. The AHP method also considers that each parameter that affects the feasibility of a groundwater recharge area has a different weight.

The selection of the priority scale becomes important to determine the groundwater recharge area in urban area as Semarang city, the capital of Central Java province. Urban areas tend to have limited open space and a high population density and high level of residential and industrial development. Several studies have been conducted to identify groundwater recharge areas in the city of Semarang, including studies conducted by [1, 6]. However, those identified areas have changed for their land use. Seeing the existing potential, these areas still have the potential to become a groundwater recharge area by implementing the right technology such as infiltration ditches or infiltration wells [1].

In contrast to previous studies, the study aims to map groundwater recharge areas involving the geographical data, the geological data, and observation results on the readiness of the community on the groundwater recharge area. The problem of Semarang city is that this area has high population density, and almost all areas are residential areas. Some of the open areas one day are transformed into a residential area. The solution to the problem offered this article is the AHP method. The AHP method was used in this article because there are two kinds of data, the first data consisted of geological and geographic data, the second data was questionnaire data.

The issue raised in this article is how to determine priorities on twenty-eight groundwater recharge areas which have been determined by previous studies [1]. This priority scale of this article assists policy makers in planning regional development, especially in the city of Semarang.

Research related to the selection of groundwater recharge areas has been carried out by many researchers. Osipov et al [16] investigated changes in the groundwater formation in Kazakhstan. This study found that the groundwater in Kazakhstan is influenced by several factors such as natural factors, climate, the geological structure, and the human activities. Previous study by Murtazin, Miroshnichenko, Trushel [17] built the system of information on "Groundwater resources and reserves of the Republic of Kazakhstan". The system consists of the document database, the graphic and semantic database. It aims to assist the evaluation of groundwater resources and reserves, and it can be endorsed for creation of the system for geoinformation and analysis of groundwater resources and reserves in Kazakhstan. Murtazin et al [18] continued his study by creating computer models of groundwater resources maps in Kazakhstan which involves the geographic information system and inputting in the graphic database. The data from GIS, remote sensing or field measurement data were used in this present study. Through reference studies that have been carried out by the authors, these researchers used a variety of variables in determining which areas are suitable for use as groundwater recharge areas. Deeksha [12] uses variables taken from GIS data such as geological maps, drainage maps, land use maps, soil texture maps, and area maps. Other researchers used data from evaporation, cost benefit, sediment, hydrology (rainfall frequency) [13]. Raviraj [14] uses data from GIS and remote sensing, the variables included maps of climate, geology, lineament, drainage density, geomorphology, slope, land use, and soils.

In the process of selecting a decision as to specify an area to be used as a groundwater recharge area can be determined by using technical data such as spatial data and could also consider non-technical issues [1]. AHP implementation method in the selection of the groundwater recharge areas by some researchers makes possible to involve non-physical data taken from the questionnaire. The data from the questionnaire from the AHP method can result in priority to an area that can be used as a groundwater recharge zone. Several studies on the selection of the groundwater recharge zones by applying the AHP method in the city of Semarang and its surrounding area are carried out by [2] [6] [8]. The research conducted by Saud [2] used the AHP method to determine the best alternative in dealing with floods in the city of Surabaya. Anjasmoro et al. [6] implemented AHP method to determine priorities for the development of reservoirs in the city of Semarang as an effort to control floods.

The AHP method is one of the methods used to assist to make a decision, especially in making choices from a number of available alternatives [11]. The emphasis of the AHP method is being able to provide solutions in determining options using an analytical approach. The researchers implemented different weight on variables used to determine groundwater recharge zones. The process of determining the weights of these variables was carried out by involving experts [14].

The research as outlined in the study aims to implement the AHP method to determine the development priority of groundwater recharge zones at the city of Semarang. In contrast to previous research, this study used two groups of variables, the first group of variables consists of five variables defined in Regulation of Ministry of Public Works PU No. 02/2013 concerning Guidelines for Preparation of Water Resources Management Plans. The second group consists of two non-technical variables for example the data on perception and knowledge related community development on the groundwater recharge areas on their territory. The technical and non-technical variables used in selecting the groundwater zone using the AHP method are expected to provide an expected description of the development of the groundwater zone priorities in the city of Semarang.

Research Methods. This research implemented the AHP method to determine the priority in groundwater recharge area at the residential area at Semarang city. AHP Method is suitable to assist the priority of the alternatives. Figure 1 shows a block diagram of the application of AHP in setting the priority on groundwater recharge area that have been identified in the city of Semarang.

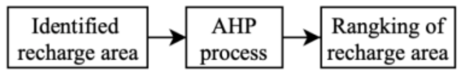

Figure 1. Block Diagram of AHP Implementation

As depicted in Figure 1, the AHP method was used to set the priority on the area that became the main priority for the development of groundwater recharge areas. In detail, the process of selecting the priority scale of groundwater recharge areas using the AHP method is shown in Figure 2.

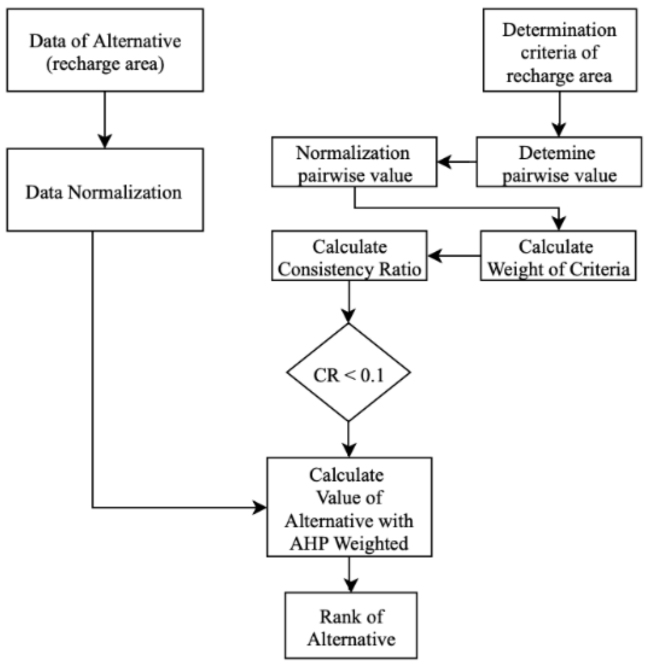

Figure 2. The Priority Scale Selection of Groundwater Recharge Areas by AHP

Figure 2 shows that the selection of the priority scale of groundwater recharge areas begins with determining the criteria and gathering the data for these criteria in a region that deserves to be a groundwater recharge area. This research used the advantage of AHP to calculate using different data forms simultaneously. As an illustration, the value of the slope (slope) uses the percentage size, the ground water level (water level) uses the millimetres, and population density uses the thousands.

The next step after determining the criteria was to determine the weight of each of these criteria. In AHP, process weighting the criteria has several stages that calculate the pair wise comparison matrix, calculate Consistency Index (CI) and finally calculate Consistency Ratio (CR). The results of the calculation of the CR value will determine whether the weight and pairwise value calculations are valid or not. If CR value is greater than 0, 1, the process of determining the criteria pairwise and weight calculation must be repeated again. Calculation of data on the criterion variable with AHP weight can be done if the CR value is less than 0.1. This calculation of the criteria and weight values will determine the final value of each alternative offered and then sorted from highest to lowest.

The ranking process of the alternatives using the AHP method began with determining criteria or variables based on the context of the problem. In this paper, the context to be resolved is to rank several areas in the city of Semarang that have been identified as groundwater recharge zones [1]. In this study, 8 criteria (variables) were taken as the basis for determining the ranking. The eight criteria are permeability, water level, slope, land use, rainfall, population density, acceptance, and knowledge. The criteria were then assigned weights as listed in Table 1. The process determining value for *pairwise comparison matrix* refers to the value of *pairwise comparison* ranged only between 1 to 9. Determination of the value of pairwise comparison was carried out by an expert who understand about the object to be studied.

Table 1. Pairwise comparison matrix determination criteria

	Criteria Comparison							
	Permeability	Water Level	Slope	Land Use	Rainfall	Population Density	Acceptance	Knowledge
Permeability (P)	1.00	0.20	0.20	0.20	3.00	0.14	3.00	3.00
Water Level (W)	5.00	1.00	0.20	0.20	3.00	3.00	5.00	5.00
Slope (S)	5.00	5.00	1.00	5.00	0.20	5.00	3.00	3.00
Land Use (L)	5.00	5.00	0.20	1.00	0.14	7.00	3.00	3.00
Rainfall	0.33	0.33	5.00	7.00	1.00	7.00	7.00	7.00
Population Density	7.00	0.33	0.20	0.14	0.14	1.00	0.20	0.20
Acceptance (A)	0.33	0.20	0.33	0.33	0.14	5.00	1.00	0.33
Knowledge (KP)	0.33	0.20	0.33	0.33	0.14	5.00	3.00	1.00
Total	24.00	12.27	7.47	14.21	7.77	33.14	25.20	22.53

After determining the value of *pairwise comparison,* the weights of the criteria were calculate, the weight of the criteria began with dividing the value of each pairwise comparison with the total values of each variable on these criteria. Table 2 presents the results of the calculation of the distribution of pairwise comparison values with the total value of the *pairwise comparison*. The mean column in Table 2 shows the AHP weight value for each of the existing criteria. Before the AHP weight values used in subsequent calculations, the consistency of the weighting was tested in the calculation of pairwise comparison matrix. The weight of the resulting criteria can be used if the consistency ratio (CR) of less than 0.1.

Table 2. Calculation of the criteria weight value, CI value, and CR value.

	Permeability	Water Level	Slope	Land Use	Rainfall	Population Density	Acceptance	Knowledge	Total	Mean
Permeability (P)	0.04	0.02	0.03	0.01	0.39	0.00	0.12	0.13	0.74	0.09
Water Level (W)	0.21	0.08	0.03	0.01	0.39	0.09	0.20	0.22	1.23	0.15
Slope (S)	0.21	0.41	0.13	0.35	0.03	0.15	0.12	0.13	1.53	0.19
Land Use (L)	0.21	0.41	0.03	0.07	0.02	0.21	0.12	0.13	1.19	0.15
Rainfall	0.01	0.03	0.67	0.49	0.13	0.21	0.28	0.31	2.13	0.27
Population Density	0.29	0.03	0.03	0.01	0.02	0.03	0.01	0.01	0.42	0.05
Acceptance (A)	0.01	0.02	0.04	0.02	0.02	0.15	0.04	0.01	0.32	0.04
Knowledge	0.01	0.02	0.04	0.02	0.02	0.15	0.12	0.04	0.43	0.05

(KP)										

Through equation 1 and 2, the CI value is -1.13, RI is 1.14, and CR is -0.99. With this CR value, the determination of Pair Wise is declared valid with a CR value <0.1.

$$CI = \frac{\lambda max - n}{n} \qquad (1)$$

CI is the Consistency Index, it is the maximum value of eigenvalue, and n is the number of variables.

$$CR = \frac{CI}{RC} \qquad (2)$$

Where CR is the Consistency Ratio and RC is the Random Consistency value.

After getting the weight value, the next step is to use that weight in the ranking process on the alternatives, in this case, the area that is suitable for use as a groundwater recharge zone. In this paper, the data were obtained through observation. Table 3 shows the data of each variable that has undergone normalization using the min max formula.

Table 3. Normalized data using min max formula

Research Location	Permeability	Water Level	Slope	Land Use	Rainfall	Population Density	Acceptance	Knowledge
Wonoplumbon	0.014	0.583	0.500	0.500	0.000	0.016	0.575	0.522
Palir	0.129	0.365	1,000	0.500	1,000	0.025	0.500	0.143
Wonolopo	0.012	0.657	0.500	0.500	0.000	0.090	0.575	0.522
Gongorio	0.021	0.127	1,000	0.500	1,000	0.641	0.500	0.143
Perum BSB	0.019	0.588	0.500	0.500	0.000	0.000	0.575	0.522
Tambak Aji	0.017	0.064	0.500	0.500	1,000	0.342	0.500	0.143
Tumbu	0.132	0.318	1,000	0.500	0.000	0.045	0.575	0.522
Perum Sriwidodo	0.011	0.030	1,000	0.500	1,000	0.743	0.500	0.143
Perum Semarang Indah	0.184	0.004	0.000	0.000	0.737	0.217	0.552	0.250
Sekaran	0.567	0.409	1,000	1,000	0.000	0.092	0.000	0.857
Dorang	0.001	0.003	0.000	0.000	0.737	0.044	0.504	0.000
Perum Jangli Permai	0.011	0.000	1,000	0.000	0.737	0.666	0.685	0.857
Perum Muktiharjo	0.017	0.004	0.167	0.000	0.737	1,000	0.254	0.536
Sendang Guwo	0.009	0.003	0.167	0.000	0.737	0.611	0.254	0.536
Sendang Mulyo	0.017	0.152	0.000	0.000	0.737	0.155	0.685	0.857
Plamongan Indah	0.015	0.044	0.000	0.000	0.737	0.335	0.254	0.536
Kolangkaling	0.168	0.619	0.500	0.500	0.000	0.204	0.575	0.522
Gunungpati	1,000	0.790	1,000	1,000	0.000	0.075	0.000	0.857
Malon	0.146	1,000	1,000	1,000	0.000	0.075	0.000	0.857
Kalisegoro	0.161	0.610	1,000	1,000	0.000	0.031	0.000	0.857
Mangunsari	0.015	0.782	0.500	1,000	0.000	0.068	0.000	0.857
Patemon	0.124	0.597	0.500	1,000	0.000	0.068	0.000	0.857
Watusari	0.008	0.760	1,000	1,000	0.000	0.075	0.000	0.857

Karang Geneng	0.012	0.762	1,000	1,000	0.000	0.075	0.000	0.857
Perum Durian	0.018	0.541	1,000	1,000	0.000	0.570	1,000	1,000
Perum Grafika	0.018	0.704	1,000	1,000	0.000	0.251	1,000	1,000
Kampung Siroto	0.013	0.704	1,000	1,000	0.000	0.394	1,000	1,000
Perum Tusam	0.000	0.506	1,000	0.000	0.737	0.147	0.685	0.857

The calculation of the ranking process in areas that have been indicated was conducted by multiplying all normalized data (Table 3) by the weight of the criteria that have been obtained in the weight calculation process based on Table 2 (mean column). The results of the calculation of each data and weight are presented in Table 4.

Table 4. Multiplication results and the criterion weight value

Research Location	Permeability	Water Level	Slope	Land Use	Rainfall	Population Density	Acceptance	Knowledge
Wonoplumbon	0.001	0.087	0.095	0.075	0	0.000 8	0.0229	0.026 1
Palir	0.012	0.055	0.19	0.075	0.27	0.0012	0.0199	0.0071
Wonolopo	0.001	0.098	0.095	0.075	0	0.0045	0.0229	0.026 1
Gongorio	0.002	0.019	0.19	0.075	0.27	0.032 1	0.0199	0.0071
Perum BSB	0.002	0.088	0.095	0.075	0	0	0.0229	0.026 1
Tambak Aji	0.001	0.009	0.095	0.075	0.27	0.017 1	0.0199	0.0071
Tumbu	0.012	0.04 8	0.19	0.075	0	0.0022	0.0229	0.026 1
Perum Sriwidodo	0.001	0.00 5	0.19	0.075	0.27	0.037 2	0.0199	0.0071
Perum Semarang Indah	0.016	0.00 1	0	0	0.199	0.0108	0.022 1	0.012 5
Sekaran	0.051	0.061	0.19	0.15	0	0.0046	0	0.042 9
Dorang	0.001	0.000 6	0	0	0.199	0.0022	0.020 2	0
Perum Jangli Permai	0.001	0	0.19	0	0.199	0.033 3	0.0274	0.042 9
Perum Muktiharjo	0.001	0.000 6	0.03 2	0	0.199	0.05	0.010 2	0.026 8
Sendang Guwo	0.001	0.0004	0.03 2	0	0.199	0.0305	0.010 2	0.026 8
Sendang Mulyo	0.001	0.02 3	0	0	0.199	0.0077	0.0274	0.042 9
Plamongan Indah	0.001	0.00 7	0	0	0.199	0.016 8	0.010 2	0.026 8
Kolangkaling	0.015	0.09 3	0.095	0.075	0	0.010 2	0.0229	0.026 1
Gunungpati	0.09	0.11 9	0.19	0.15	0	0.003 8	0	0.042 9
Malon	0.013	0.15	0.19	0.15	0	0.003 8	0	0.042 9
Kalisegoro	0.014	0.09 2	0.19	0.15	0	0.0015	0	0.042 9
Mangunsari	0.001	0.117	0.095	0.15	0	0.003 4	0	0.042 9
Patemon	0.011	0.089	0.095	0.15	0	0.0034	0	0.042 9
Watusari	0.001	0.11 2	0.19	0.15	0	0.0037	0	0.042 9
Karang Geneng	0.001	0.114	0.19	0.15	0	0.0037	0	0.042 9
Perum Durian	0.002	0.081	0.19	0.15	0	0.0285	0.04	0.05
Peum Grafika	0.002	0.10 6	0.19	0.15	0	0.012 6	0.04	0.05
Kampung Siroto	0.001	0.10 6	0.19	0.15	0	0.019 7	0.04	0.05

Perum Tusam	0	0.07 6	0.19	0	0.199	0.0073	0.0274	0.042 9

The final process of calculating these values was to add up each value horizontally according to the available object or alternative. The total number of values for each of these alternatives is the basis for determining the rating of each alternative. The final result of calculations using the AHP method was the priority ranking of the groundwater recharge development in the city of Semarang as contained in Table 5.

Results and Discussion. In this study, an order of priority development of groundwater recharge areas in the city of Semarang is shown in Table 5. The process of development of groundwater recharge area starts from the Palir village, Ngaliyan sub-district to Karang Geneng village, Gunungpati sub-district. Utilization of AHP in determining the priority of the alternatives used both regional geomorphological conditions and the readiness of the local community. In fact, now it is quite difficult in an urban area that has open area to be used as a groundwater recharge area. The results of this study are expected to provide an overview of the residential areas which geomorphologically have potential as groundwater recharge area and community preparedness. It is also expected that residential areas could be built permanently and maintain their functions as residential areas.

Table 5. The results of the ranking of groundwater recharge areas in the city of Semarang

No.	Villages	Sub District	Score
1	Palir	Ngaliyan	0.629 6
2	Gondoriyo	Ngaliyan	0.615 1
3	Perum Sriwidodo	Ngaliyan	0.60 4 8
4	Gunungpati	Gunungpati	0.595 1
5	Kampung Siroto	Banyumanik	0.556 4
6	Perum Grafika	Banyumanik	0.549 8
7	Malon	Gunungpati	0. 5 49 7
8	Perumahan Tusan Tembalang	Tembalang	0.542 5
9	Perumahan Durian	Banyumanik	0.541 3
10	Karang Geneng	Gunungpati	0.502 9

Table 5 shows that some areas has small value geomorphologically, which (0) in the normalized data but in the area is prioritized for the groundwater recharge development. The value of 0 in normalized data occurs because the data has a minimum value to other values on that criterion. Therefore, the value of 0 in this condition does not mean that the area does not have potential. The involvement of the data acceptance and knowledge on a region has a significant contribution in providing an assessment of the area feasibility for the groundwater recharge.

This section highlights the advantages of using the AHP method in determining a ranking process. However, this method also has some weaknesses. One of which is the result of the ranking process can be changed because it is based on values that are arranged in pairwise comparison matrix. These values determine the weight of each existing criterion. The process of drafting the values in the pairwise comparison matrix highly depends on the experts who justify those values. Therefore, if the pairwise comparison matrix composed by different experts could only produce different weights and can affect the final result ranking of the alternatives.

Conclusion. In the study resulted in 10 prioritized areas at the city of Semarang who qualifies groundwater recharge areas. These ten areas are not all open areas but there are also residential areas which is geomorphologically suitable as a groundwater recharge area. The result shows that the areas which have been geomorphologically identified and coupled with the knowledge and acceptance of the community towards a groundwater recharge area can allow them to have the potential as groundwater recharge areas. Through the application of appropriate governance and technology, it is possible for all identified areas to have potential as groundwater recharge areas to serve as water reserves in urban areas.

In contrast to previous research on the determination of groundwater recharge areas in Semarang which only determined locations, the results obtained from this research allows the gradual development on the identified areas. The results of this study can provide a priority scale for the development of groundwater recharge areas in the city of Semarang.

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СЕМАРАНГ ҚАЛАСЫНДА ҚАЙТА ҚУАТТАНДЫРУ АЙМАҚТАРЫНЫҢ АРТЫҚШЫЛЫҒЫН АНЫҚТАУ ҮШІН АНР ӘДІСІН ҚОЛДАНУ

Абстракт. Белгілі бір аймақты жерасты суларын қайта толтыратын аймақ ретінде таңдау аймақты дамытуға басымдықты қажет етеді. Қалалық жерде таза сумен жабдықтауды қамтамасыз етуде жерасты суларын қайта толтыру аймағы маңызды рөл атқарады. Қалалық аймақ дегеніміз - қарқынды дамуды, әсіресе тұрғын үй мен өндірістік аймаққа айналған жерді пайдаланудағы өзгерістерді бастан кешетін аймақ. Бұл талқылауда Аналитикалық иерархия процесі (AHP - Analytical Hierarchy Process) әдісі Семаранг қаласындағы су жинау аймағын дамытудың басым шкаласын анықтау үшін қолданылды. AHP әдісі аумақты анықтауда қолданылатын айнымалылардағы мәліметтерге негізделген етіп әртүрлі өлшемдерге ие деректерді бір уақытта талдау үшін пайдаланылды. Талдау нәтижелері бойынша жер асты суларын қайта толтырудың 10 басым бағыты және олардың рейтингі шығарылуы мүмкін, олар біртіндеп Семаранг қаласында су жиналатын аймақ ретінде дами алады.
Түйін сөздер: AHP әдісі, суды қайта зарядтау алаңы, басымдық шкаласы, рейтинг.

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ВНЕДРЕНИЕ МЕТОДА AHP ДЛЯ ОПРЕДЕЛЕНИЯ ПРИОРИТЕТА ДОПОЛНИТЕЛЬНЫХ ЗОН В ГОРОДЕ СЕМАРАНГ

Абстракт. Выбор определенного региона для пополнения запасов подземных вод требует приоритета развития региона. Зона пополнения запасов подземных вод играет важную роль в поддержании чистой воды в городских районах. Городская территория - это область, которая быстро развивается, особенно изменения в землепользовании, которые превратились в жилые и промышленные районы. В этом обсуждении метод Аналитического Иерархического Процесса (AHP - Analytical Hierarchy Process) был использован для определения приоритетного масштаба развития зоны охвата в городе Семаранг. Метод AHP использовался для одновременного анализа данных, имеющих множество измерений, поэтому он основан на данных, содержащихся в переменных, используемых при идентификации области. По результатам анализа можно получить 10 приоритетных областей для пополнения запасов подземных вод и их ранжирование, которые можно постепенно развивать в качестве водосборных территорий в городе Семаранг.
Ключевые слова: Метод AHP, область водоснабжения, шкала приоритетов, рейтинг.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

PAGE 10