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Groundwater Quality Assessment And Recharge Well Design Of Cengkareng Area, West Jakarta

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Abstract

Cengkareng sub-district in West Jakarta has experiencing periodic flooding. Land use change from open space area into settlements and business area has increased surface runoff that causing flooding. Also, activities in these areas had caused groundwater pollution and groundwater level declined. Groundwater recharge well is one of many methods to increase groundwater level by utilizing storm water infiltration. Thus, storm water that causing inundation could be converted to recharge the groundwater. This research was performed quality and quantity analysis to study existing groundwater condition. The hydrochemistry of groundwater in all sampling locations shows high NH_4 ranging from 2.3 mg/L to 19.02 mg/L indicate groundwater contamination suspected originated from domestic/non domestic waste or septic tank leakage. Also, one of five sampling locations shows Na and EC value which exceeds the permissible limit that might due to salt intrusion. Regarding groundwaterlevel for Cengkareng area, the result shows that there is a significant groundwater level decline at ’deeper confined aquifer (>140)’ wells from 2005 to 2013. The groundwater level trend line shows that the groundwater level will continue to decrease in the future. There is no groundwater decline at ‘above confined aquifer (40-140 m)’ wells, but groundwater level is very low at around -58 m AMSL. This could be the result of intensive groundwater withdrawal that has been occurring years ago until now. Hence, groundwater recharge in this area is critical, in order to restore groundwater storage. Therefore, the artificial recharge of storm water, will work on reducing the groundwater pollutant and increasing the water level.

Finally, the design of infiltration wells was completed using Sunjoto Formula and rainfall data of Cengkareng, with soil permeability of 14x10^{-6} m/s.

Key words: Groundwater level, Hydrochemical characteristics, Recharge well, Cengkareng

1. INTRODUCTION

The rate of population growth of Jakarta has causing an increasing in water demand. About 64% of the Jakarta population and the majority of industries rely on groundwater [1]. The need for clean water is still dependent on groundwater is estimated at around 70% [2]. Groundwater usage in Jakarta is increasing year by year, its groundwater level and quality has declined [3]. Ground water is a natural resource that can be renewed, but the formation process takes years to reach tens of thousands of years. If the ground water has damaged both quantity and quality, the recovery process takes a long time also with the high cost and complicated technology which can not even be returned to its original state.

Higher population growth also result in increasing demand for settlements, and other infrastructures had caused changes in land use. The removal of vegetation and creation of hard surfaces, rainwater infiltration and natural groundwater recharge decrease [4]. This results in increased runoff rates and volumes; reduced infiltration, groundwater recharge, and base flow to urban stream [5, 6]. This changed hydrology then causes environmental impact including declining water quality due to increases in sediment, nutrients, and heavy metal [7]. Urban settlements are the main source of point source pollution. Various pollutants that accumulate on impervious surfaces during dry periods are subsequently washed off during storm events and then discharged into receiving waters [4].

Recharge wells is one of the engineering buildings in the form of water conservation techniques that made such that resembles the shape of dug wells with a certain depth which serves as the rainwater that falls on the roof of the house or the area watertight and infiltrate it into the ground. With this recharge wells, rain water will be collected and absorbed into the soil, thereby improving soil water and reduce runoff. So as to reduce flooding and provide ground water in the dry season so that the wells and springs that there may still watering in times of drought[8].The working principle is the infiltration wells and rainwater channeled into holes or wells so that water can have the time living in mobile soil surface longer so that little by little water can seep into the ground [9]. The more water that flows into the ground could mean a lot of water stored in the soil below the surface of the Earth. Water can be used back through wells or springs that can be explored at any time [10].

As flooding periodically occurs in Cengkareng Sub-district area, recharge well by rainwater could be applied in this area. So, in order to investigate application of recharge well in this area, firstly, groundwater quality and quantity assessment are to be carried out. The main objectives of the present study are: 1) to analyze the hydrochemistry of groundwater, 2) to analyze changes in ground water level in the Cengkareng area, and 3) designing an infiltration wells for household scale.

2. RESEARCH METHOD

2.1 Sampling Area

Sampling area of groundwater level and hydrochemistry is the Cengkareng sub-district which consists of residence and factory area. It is located in the west of Jakarta City. The longitude lies on 106º22’42” E - 106º58’18” E and latitude 5º19’12” S - 6º23’54” S. Sampling locations of groundwater level study are in 2 (two) locations (Figure 1.a), they are monitoring wells in: I. Kapok Village Office and II. PT. ABC Battery Factory. Meanwhile, groundwater samples for hydrochemistry analysis were taken from 5 (five) locations (Figure 1.b), where sampling well number 1, 2, 3, and 4 located at the same kampong, and sampling well number 5 located near Cengkareng Drain Channel (5 m width, 3 m deep open channel).

2.3. Groundwater Hydrochemistry Analysis

Hydrochemistry parameters analyzed were pH, Na (Sodium), NH_4 (Ammonium), K (Potassium), Ca (Calcium), Mg (Magnesium), Cl (Chloride), NO_3 (Nitrate), SO_4 (Sulphate) and TDS (Total Dissolved Solids). Major cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) and anions (Cl^-, SO_4^{2-} $NO_3^-$and NH_4^+) were analyzed using ion chromatography[11].The result was compared to the permissible limit or drinking water quality standard of PERMENKES No. 492 / Menkes / Per / IV / 2010 [12]. In dilute solution, TDS and EC are reasonably comparable. The TDS of a water sample based on the measured EC value can be calculated using the following equation [13]: TDS (mg/l) = 0.65 x EC (mmho/cm). EC and pH were measured using digital meters immediately after sampling.

2.2. Groundwater level Analysis

In analyzing groundwater level at Cengkareng sub-district, required a high secondary data ground water obtained from the Bureau of Geology and Environmental Management. The groundwater in monitoring wells of Kapok Village office and PT. ABC Battery Factory categorized as ‘above confined aquifer (40-140 m)’ and ‘below the confined aquifer (> 140 m)’, respectively, based on map of groundwater contour of confined aquifer (see Figure 2). Groundwater level data are then plotted into a graph to see changes in ground water level that occurred in each year. Then analyzed changes in groundwater levels using the method of logical analysis is to explain the causes of changes in ground water level graphs the number of wells drilled in Cengkareng on year.

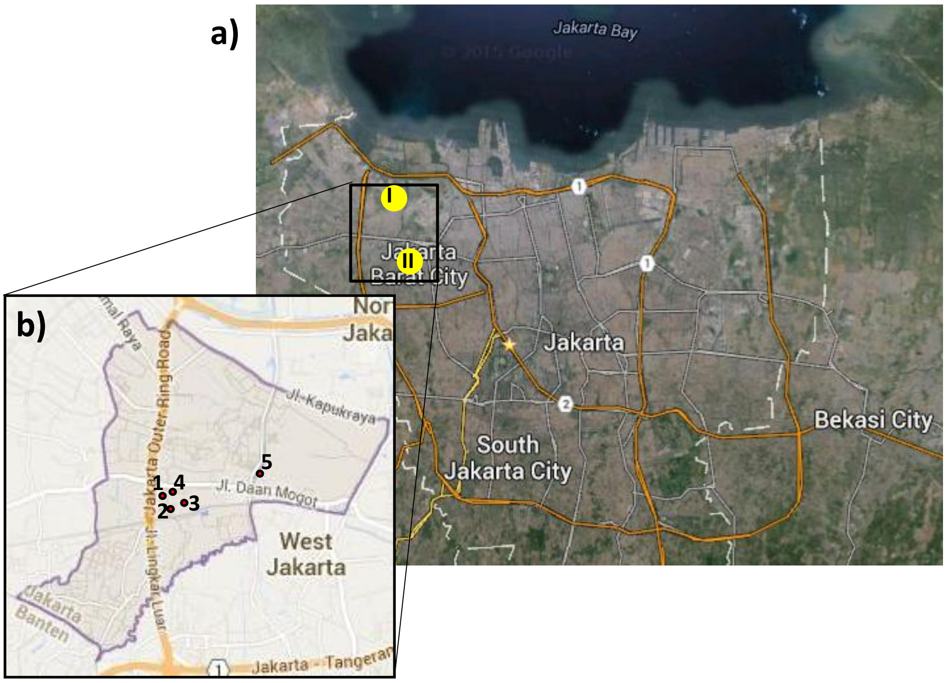

Figure 1. Sampling location of study of groundwater level (a) and groundwater quality (b) in CengkarengSub-district, West Jakarta Regency, Jakarta

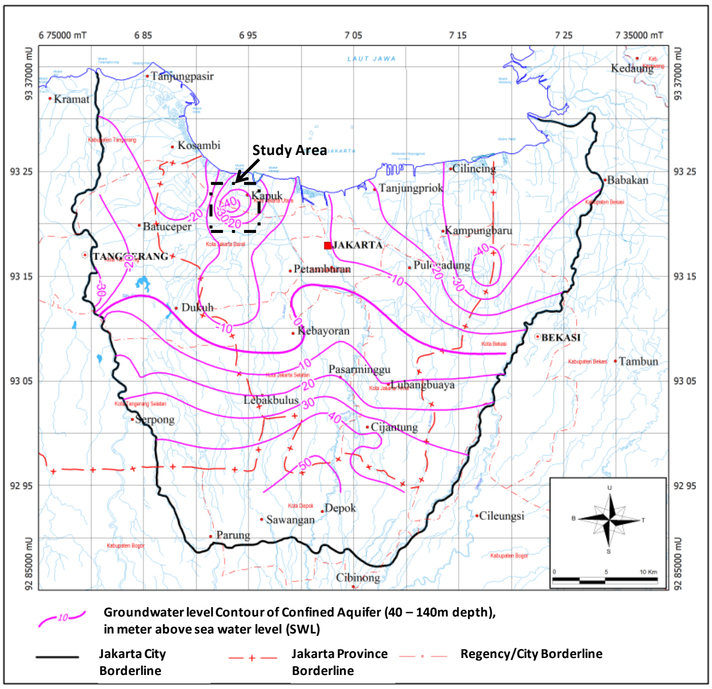

Figure 2. Map of Groundwater contour[14] and study area shown in dot-dashed square.

2.4. Recharge Well Design

Recharge wells is infrastructure to accommodate and absorb rainwater into the ground (see Figure 3). The main purpose of the infiltration wells is to enlarge the entry of water into the aquifer as the ground water infiltration (infiltration). Thus, more water will get into the soil and a little stream that flows as a surface (runoff). Thus, the entry of rain water into the ground will make the groundwater recharge will increase the amount of ground water in the aquifer layer [15].

The recharge well using storm water is installed in a backyard. Ministry of public work released a guidelines in SNI No. 03-2453-2002 [16] had established the technical data of water infiltration wells are as follows: 1) The maximum size of 1.4 meters diameter, 2) The size of the inlet pipe diameter of 110 mm, 3) overflow pipe size diameter 110 mm, 4) depth Size 1.5 up to 3 meters, 5) the walls are made of masonry or brick of a mixture of 1 cement: 4 sand without plaster, 6) At the bottom of well, 40 cm high of stone d 20 mm was placed, 7) top cover of wells is10 cm thick concrete slab (1 cement: 2 sand: 3 gravel).

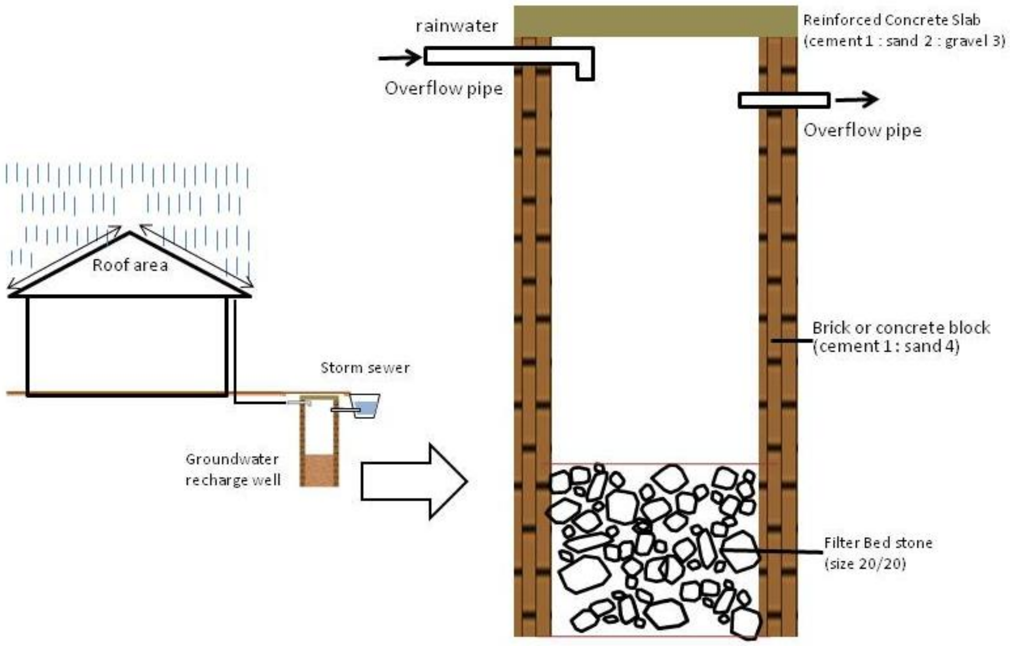

Figure 3. Schematic diagram of storm water recharge well facility and its design.

Before performing the calculation of the dimensions of well catchment, rainfall analysis previously required to obtain the design discharge (Q). Rainfall data used maximum rainfall data. It is intended that the analysis can approximate the actual conditions on the ground. Rainfall data is obtained from Cengkareng Drain Rainfall Station located in the vicinity of the study area which represents the frequency of precipitation at Cengkareng sub-district catchment area. Rainfall data from 2003 to 2013 were obtained fromCiliwung-Cisadane Watershed Management Bureau. The storm water discharge design was calculated with return periods of 2, 5, 10, 25, 50, and 100 years. The calculation of recharge wells design for each class conducted by Sunjoto roof[17], where variables such as soil permeability, debit entries, the geometric factor, the radius of the well, and duration of rainfall has been calculated first. Soil permeability of soil data obtained from the Department of Industry and Energy in the data recharge wells for RawaBuaya Village. Volume and efficiency of recharge wells can be calculated based on the balance of water into the well and the water seeped into the ground [17], the formula to calculate the depth of recharge well is as follows:

$$H= \frac{Q}{F \times K}\left(1-e^{-\frac{F \times K \times T}{S}}\right) \qquad (1)$$

Where:
H = Depth of recharge wells (m)
Q = Input discharge (m^3 / s)
T = Flow duration (seconds)
F = Geometric factor
K = Soil permeability (m / sec)
s = Area of well (m^2)

3. RESULT AND DISCUSSION

3.1. The Quality of Groundwater

Hydrochemistry characteristics of groundwater of all sampling locations are shown in Table 1. The pH levels of five locations are within health-based drinking water standard, it is inside the range of 6.5 to 8.5. The pH value outside of this range can lead to high dissolved concentration of some metal for which there are potential health effect [18].

The concentration of K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, and SO_4^{2-} in all locations are still within the water quality standard or non-polluted limits. Ammonium (NH_4) concentration in all locations is within the range from 2.3 mg/L to 19.02 mg/L which exceeds the permissible limit of 1.5 mg/L. The highest concentration is at location 5 of 19.02 mg/L. Ammonium can be derived from waste water, organic manure, urine and feces, as well as from the oxidation of organic substances derived from natural microbiology or waste (domestic and non-domestic). Regarding waste from urine and feces, it is suspected originated from septic tank leakage that infiltrate to groundwater, as found in a study by Vollard et al [19] using microbiological parameter. It could be concluded that the groundwater in all sampling locations of Cengkareng sub district might be contaminated by septic tank, domestic and/or non-domestic waste water. Location 5 situated near Cengkareng drain, thus the groundwater might have also polluted by ammonium contaminated surface water in Cengkareng drain that infiltrate to the groundwater. As found in a study by Sidauruk et al [20] that degradation of water quality could occur due to the movement of surface water to groundwater or contaminated water to groundwater. However, further investigation should be conducted by utilizing tracers.

TDS (Total Dissolved Solid) content is slightly over the permissible limit of 500 mg / L also found in location 5 sample with TDS value of 572.76 mg / L. TDS values exceeding 500 mg / L can be considered contaminated. However, reliable data on possible health effects associated with the ingestion of TDS in drinking water are not available. High TDS levels (>500 mg/L) result in excessive scaling in water pipes, water heaters, boilers, and household appliances such as kettles and steam irons. Such scaling can shorten the service life of these appliances [21].

Table1 Hydrochemistry of Groundwater

Sample	Parameter										
	pH	TDS	EC	Na^+	NH_4^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	NO_3^-	SO_4^{2-}
	-	mg/L	mmhos/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Location 1	7,52	140,62	216,338	24,06	3,42	16,65	27,28	6,24	15,74	35,18	12,05
Location 2	7,39	76,63	117,892	11,92	2,30	8,12	28,00	6,23	14,23	2,67	3,16
Location 3	7,32	254	390,769	35,35	6,69	10,80	87,29	20,22	48,49	31,35	13,81
Location 4	8,38	194,95	299,923	35,01	5,09	10,60	85,35	20,31	31,01	2,80	4,78
Location 5	6,84	572,76	881,169	396,5	19,02	1,21	6,65	4,32	80,04	34,55	30,46
Standard	6,5 – 8,5	500	750	200	1,5	85	75	30	250	50	250

Concentration of Na in location 5 exceeds the maximum limit of 200 mg/l, as Na concentration in this location is 396.51 mg/L. This higher sodium is probably due to sea water intrusion as sample from well in location 5 is located ± 1 km to Cengkareng Drain where the outlet is at the estuary of Java sea (about ± 6 km).

EC is measured inmillimhos per centimeter (mmho/cm) and is measure of salt content in the form of ions [22]. In this study, EC value in location 5 is 881.169 mmho/ cm which exceeding permissible limit of 750 mmho/cm. High value of EC shows existence of high salt ions. Hence, the study area has been contaminated with seawater intrusion.

Hydrochemistry analysis results shows in accordance with the study result by Varis et al [23], that concluded groundwater in Jakarta had suffer over-abstraction causing remarkable saltwater intrusion into the main aquifers and also, groundwater pollution from domestic waste.

3.2. The Groundwater Level Trend

Groundwater level, as a time series, is shown in Figure 4 for two types of aquifer, ‘above deep confined aquifer (40-140m)’ and ‘deeper confined aquifer (>140 m)’ located in Kapuk Village Office and PT. ABC Battery Factory, respectively. Result shows that at ’deeper confined aquifer (>140)’ wells there is a significant groundwater level decline. There is a decrease in 2005 of 2.35 m from -25.50 m Above Mean Sea Level (AMSL) to -27.85 m AMSL. Then there is a decline as much as 17.47 m in year 2010 to 2012, from -23.10 m AMSL to -40.57 m AMSL. In 2013 there is an increase to -31.78 m AMSL. In general, at 'deeper confined aquifer (>140)', the groundwater level trend line shows groundwater level decline with an average decline of 1.98 m/year.

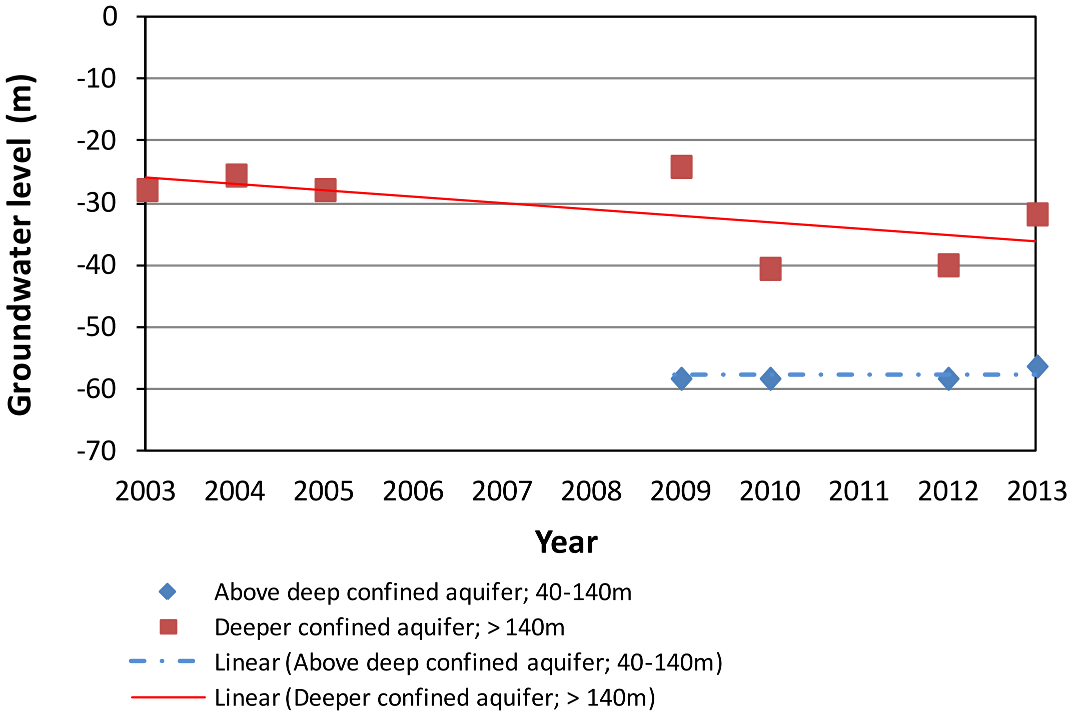

Figure 4. Groundwater level trend line of above confined aquifer (40 – 140 m) and deeper confined aquifer (>140m)
(*Source : Analysis Result 2014*)

There is no groundwater decline at 'above confined aquifer (40-140 m)' wells, but groundwater level is very low at around -58 m AMSL from year 2009 to 2013. This could be the result of intensive groundwater withdrawal in many wells at Kapuk Village Office area, which has been occurring years ago until now. The groundwater recharge rate could not balance the groundwater abstraction rate that caused the lowering of groundwater level [24].

3.3. Dimension of Recharge Wells Design

Recharge wells were designed to accommodate discharge design of various return periods of rainfall intensity and roof areas. As the diameter of recharge well is 1 m, the depth of recharge well are varied based on storm water discharges from various roof areas and return period of rainfall intensity. Using formula (1), the depth of recharge well calculation result can be seen in Table 2.

Table2 Depth of Recharge Wells

Roof Area*) (m^2)	The depth of recharge (m) for return period					
	2 yrs	5 yrs	10 yrs	25 yrs	50 yrs	100 yrs
21	0.44	0.62	0.75	0.90	1.01	1.13
36	0.76	1.07	1.28	1.54	1.74	1.93
45	0.95	1.34	1.60	1.93	2.17	2.41
60	1.26	1.79	2.13	2.57	2.89	3.22
70	1.47	2.08	2.49	3.00	3.38	3.75
80	1.68	2.38	2.84	3.43	3.86	4.29
100	2.10	2.98	3.55	4.28	4.82	5.36

*Note: *) Class of roof area (Sunjoto, 1991)*

4. CONCLUSION

Rain water in Cengkareng sub-district, West Jakarta, should be utilized to recharge the groundwater by applying groundwater recharge well. From the results obtained, the following conclusions are derived:

1. The pH levels of five locations are within health-based drinking water standard, it isinside the range of 6.5 to 8.5. The pH levels are as follows: 7.52; 7.39; 7.32; 8.38; and 6.84. The concentration of K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, and SO_4^{2-} in all sampling locations are still within the water quality standard ornon-polluted limits. However, ammonium (NH_4) concentration in all locations is within the range from 2.3 mg/L to 19.02 mg/L which exceeds the permissible limit of 1.5 mg/L. So it could be concluded that the groundwater in all sampling locations of Cengkareng sub district might be contaminated by septic tank, domestic and/or non-domestic waste water, aspollutant source of ammonium.Salt intrusion might occur as detected in higher Na and EC load compare to water quality standard.
2. Groundwater level decline take place at 'deeper confined aquifer (>140)' wells from 2005 to 2013. There is no groundwater decline at 'above confined aquifer (40-140 m)' wells, but groundwater level is very low at around -58 m AMSL. This could be the result of intensive groundwater withdrawal that has been occurring years ago until now.
3. The depth of infiltration wells is calculated based on the class of the rooffrom 21 m^2 to 100 m^2 with various return period. The depth of infiltration wells with 2-yrs, 5-yrs 10-yrs, 25-yrs, 50 yrs, and 100-yrsreturn period is 0.44 m to 2.10 m, 0.62 m to 2.98 m, 0.75 m to 3.55 m, 0.90 m to 4.28 m, 1.01 m to 4.82 m and 1.13 m to 5.36 m, respectively.
4. Water level decline is associated with increasing groundwater salinity; hence the correlation between declining groundwater levels and changing quality should be evaluated.

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