JOURNAL OF
ENVIRONMENTAL HYDROLOGY

The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com

VOLUME 7 1999

HYDROGEOLOGICAL PERFORMANCE ASSESSMENT OF AGROWELLS, SRI LANKA

H.U.S. Wickramaratne Institute of Fundamental Studies, Kandy, Sri Lanka
A. I. Adhihkari Groundwater Section, National Water Supply and Drainage Board, Anuradhapura, Sri Lanka
H.A. Dharmagunawardhane Department of Geology, University of Peradeniya, Sri Lanka

The hydrogeological parameters of large diameter dugwells that are used for agricultural purposes, called agrowells, were studied. All agrowells investigated in the drainage basin can be categorized into four major regions (namely upper, middle, lower catchment and close to irrigation reservoirs). Except for agrowells close to irrigation reservoirs, the other three categories can be grouped into small units with respect to geology. The hydrogeological performance is different depending on region and geology. The study results show that (1) water levels in the upper and middle regions has gradually declined since construction, (2) the lateral influence of water levels in the agrowells is limited (i.e. 300 m), (3) the water level of agrowells has been maintained by irrigation reservoirs, and (4) recharge and drawdown has been maintained by the design of agrowell lining walls.

INTRODUCTION

Water is perhaps the most basic resource. Yet, in many parts of the world, it is an extremely scarce and hence a most valuable resource (Dissanayake, 1989).

Sri Lanka receives about 12 million-hectare meters of water annually from rainfall, of which more than 50 percent is lost through evapotranspiration. Another 20 percent seeps down to replenish groundwater while only 30 percent, or about 3.5 million-hectare meters, is available as streamflow for irrigation or other purposes. With the average annual rainfall varying from 1000 mm to over 5000 mm, there are considerable time and space variations in Sri Lanka's surface water balance.

Since metamorphic rocks cover about 90 percent of the island, very little is known about the groundwater potential in this large region (Dissanayake, 1989). Lawrence and Dharmagunawardhane (1983) showed that the North and Northwest region is underlain by limestones of Miocene age, which extend over an outcrop length of over 200 km. At the Vanathavilly basin, covering over 40 km^2, groundwater resources are estimated to range from 5 to 20 million cubic meters per year. According to them, recharge to Miocene limestone does occur despite the fact that geological conditions preclude the possibility of lateral flow from outside the basin. Their hydrogeochemical and pumping tests have shown that recharge occurs as leakage through the semi-permeable cover.

In addition to its traditional use for domestic purposes, groundwater is now being used for small scale irrigation, especially in the dry zone area of Sri Lanka to cultivate short term crops. These include chilly, onions, vegetables and paddy cultivation. In some areas large diameter (typically 5 to 6 m) dugwells called "agrowells" are used . The depth of these wells ranges from 6 to 8 m.

The Agriculture Development Authority started the agrowell program in the Anuradhapura district in 1989. The overall aim of this program was to assist farmers in the cultivation of crops in the vicinity of homesteads, and in highland areas where cultivation traditionally depended on rainfall. However, the growing enthusiasm of farmers about agrowell use has increased with financial support schemes introduced by governmental as well as non-governmental organizations. In the present case study, the Kalaoya basin in the Anuradhapura district was selected for the investigation of various aspects of agrowells. The average annual rainfall in the area is about 1400 mm. The area experiences two rainy seasons, the "Yala" and the "Maha". The Yala season begins in mid-March and ends in May or June. The Maha season begins in October and ends in late December. This season gives the highest rainfall.

Dharmasena (1995) has shown that the availability of water in shallow dug wells in this area varies over a wide range according to the existence of surface water bodies, aquifer characteristics, seasonal rainfall, rate of groundwater extraction, and watershed characteristics. Wickramaratne and Dharmagunawardhane (1997) have shown that the behavior of agrowells depends mainly on rainfall patterns, geomorphology and the position of the agrowells within the drainage basin.

The present work shows the behavior of agrowells with regard to geology, hydrogeology, geomorphology and rainfall.

MATERIALS AND METHODS

Aerial photographs and topographic and geologic maps were used for identifying structure, geology, geomorphology and drainage patterns, and to register the agrowell location (Figure 1). A well survey was carried out on agrowells to obtain hydrogeological data. The water levels in the agrowells were measured during the rainy and dry seasons, and also, for a limited number, during

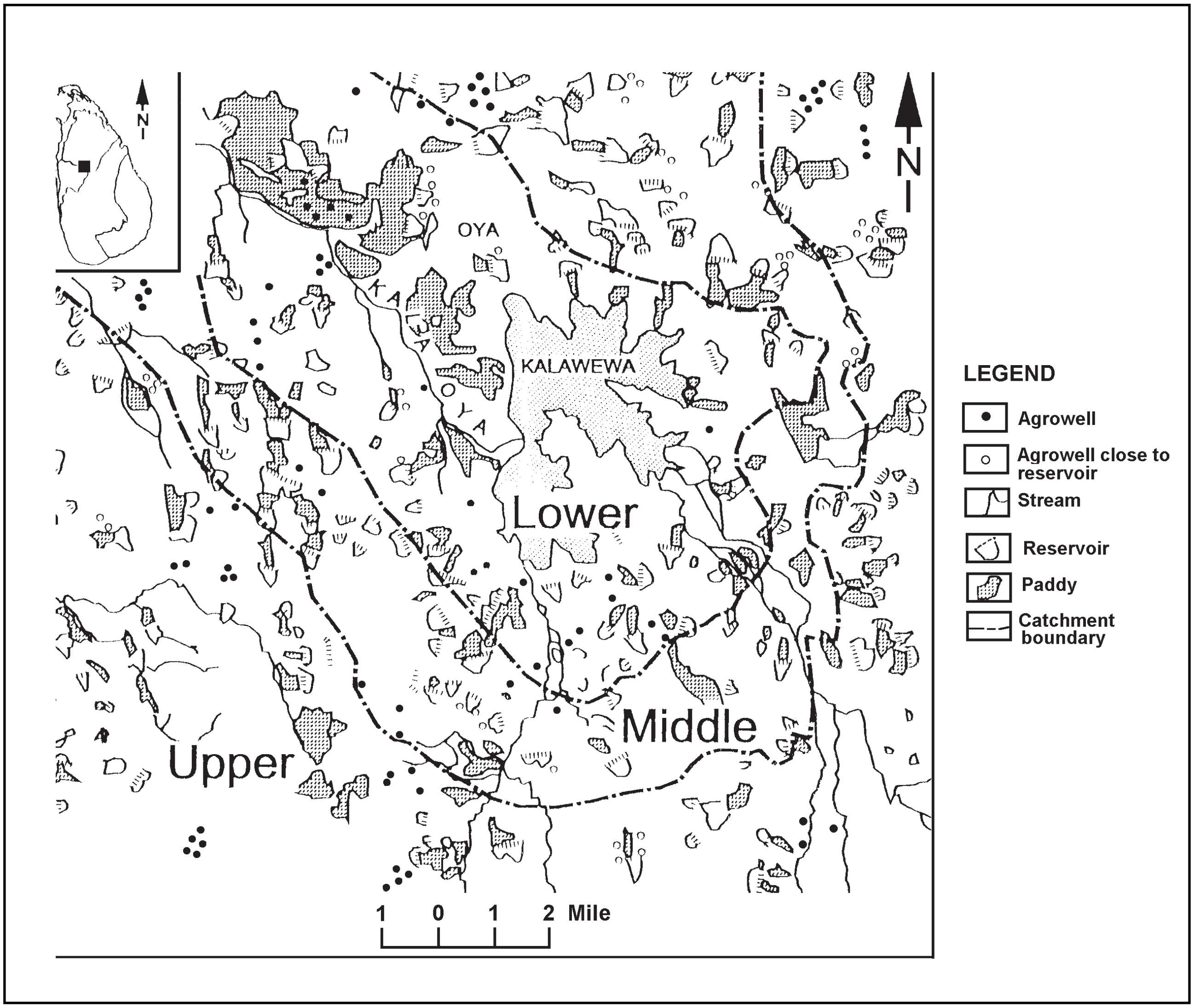

Figure 1. The map showing the locations of agrowells.

pumping and recovery. All other information about agrowells was obtained after discussions with owners, and these data were collected with an agrowell inspection data sheet.

GEOLOGY, GEOMORPHOLOGY, HYDROGEOLOGY OF THE AREA

The geology of the drainage basin is dominated by crystalline Precambrian basement rocks (Cooray, 1984). All rock types show a general strike direction of NNE-SSW and moderate dip towards west. Some large scale tight folding is seen locally. Regional fault and joint zones and a large number of small scale lineaments can be located on the aerial photographs, especially in the southern and western parts of the area.

The study area is a low lying plain with undulating land surface which gradually increases in elevation towards the southwest, where a few isolated hills are present. The main water-bearing formations in the area are the weathered overburden and fractured and jointed crystalline basement rocks. The thickness of the overburden varies from 0 to 20 m, with an average thickness of approximately 7 m. The depth of the water table varies between 1 to 10 m, with an average seasonal fluctuation of 4 m. Figure 2 shows the geological map of the study area.

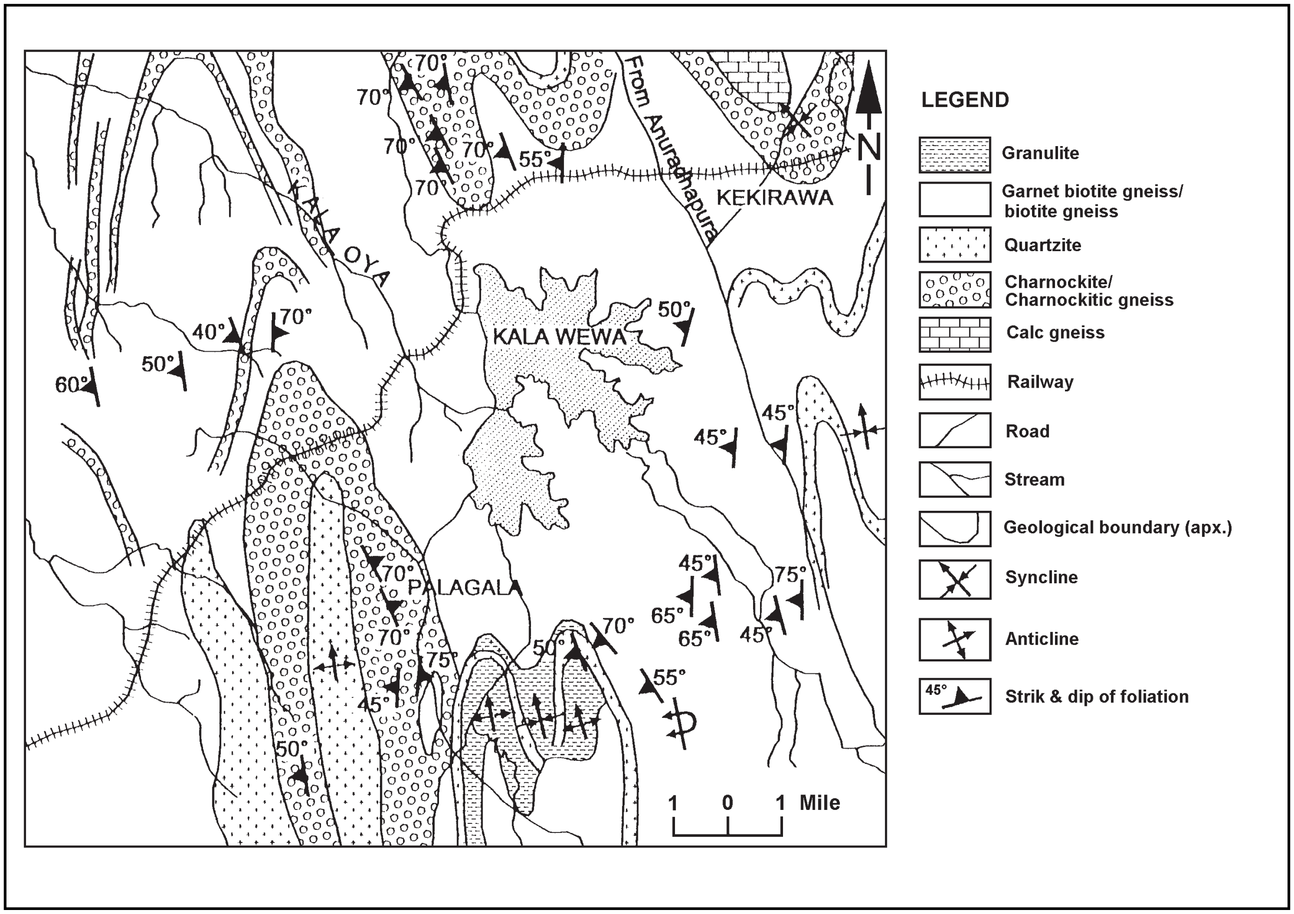

Figure 2. Geological map of the study area.

RESULTS AND DISCUSSION

Design and performance of agrowells

Many agrowells are lined with bricks or rubble masonry work. The majority of wells is located in the lower and middle part of the basin. A large number of agrowells are located close to irrigation reservoirs. They are maintained mostly by direct seepage from the reservoirs.

All agrowells investigated in the drainage basin can be morphologically categorized in to four major groups irrespective of the morphology in the drainage basin: (a) upper (UA), (b) middle (MA), (c) lower part of the catchment area (LA), and (d) wells that are located in close proximity to irrigation reservoirs (RA) (Figure 1). Except in the case of the RA group, the other categories can be grouped into smaller units with respect to their geology.

Agrowells in the upper catchment region

About 20 percent of the agrowells are located in the upper catchment area. Most extend through the soil overburden and some into the fractured (partially weathered) rock. During pumping, agrowells show different drawdown and recovery in different rock types. Figure 3 shows the uniform drawdown of agrowells in all rock types in UA region except in agrowells on biotitegneiss where drawdown is less (6m). Recovery of agrowells on granulite and quartzite shows a similar pattern. Agrowells in charnockite and biotitegneiss has another pattern. The water level in each rock type varies (Figure 3, quartzite 8m, granulite 7.5m, biotitegneiss 5m, charnockite (3m). This may be due to different overburden conditions and different fracture density. All agrowells have shown a decrease in discharge and recovery rate since their construction except for agrowells in biotitegneiss.

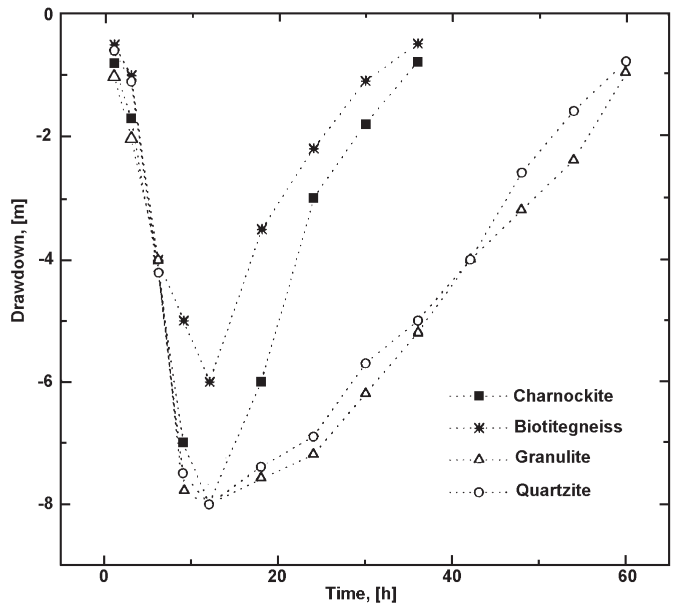

Figure 3. Daily drawdown and recovery of water level in agrowells in the upper region.

During pumping of the agrowells, water levels in nearby wells also drop depending on the geological structure which controls the flow of groundwater.

Agrowells in the middle catchment region

About 25 percent of the agrowells were investigated in middle catchment region. During pumping agrowells behave similarly in both charnockite and biotitegneiss (Figure 4). Drawdown is slightly

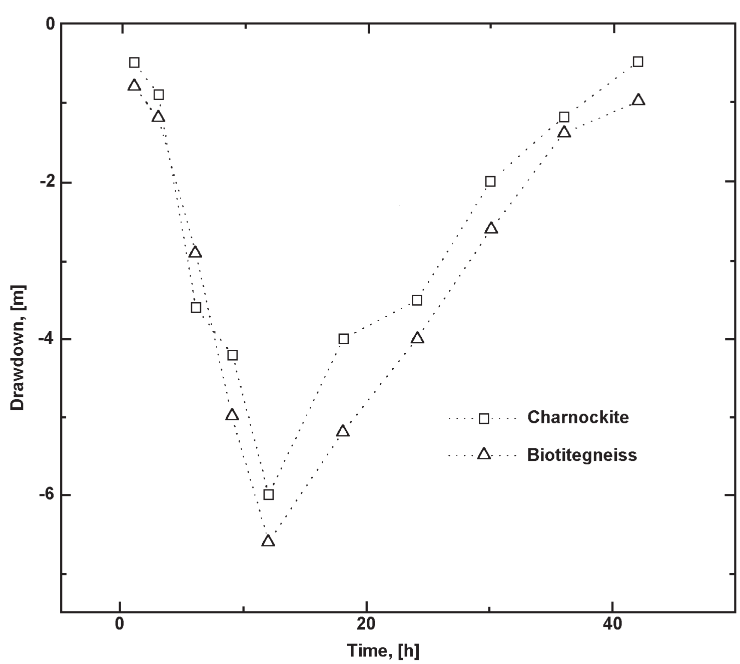

Figure 4. Daily drawdown and recovery of water level in agrowells in the middle region.

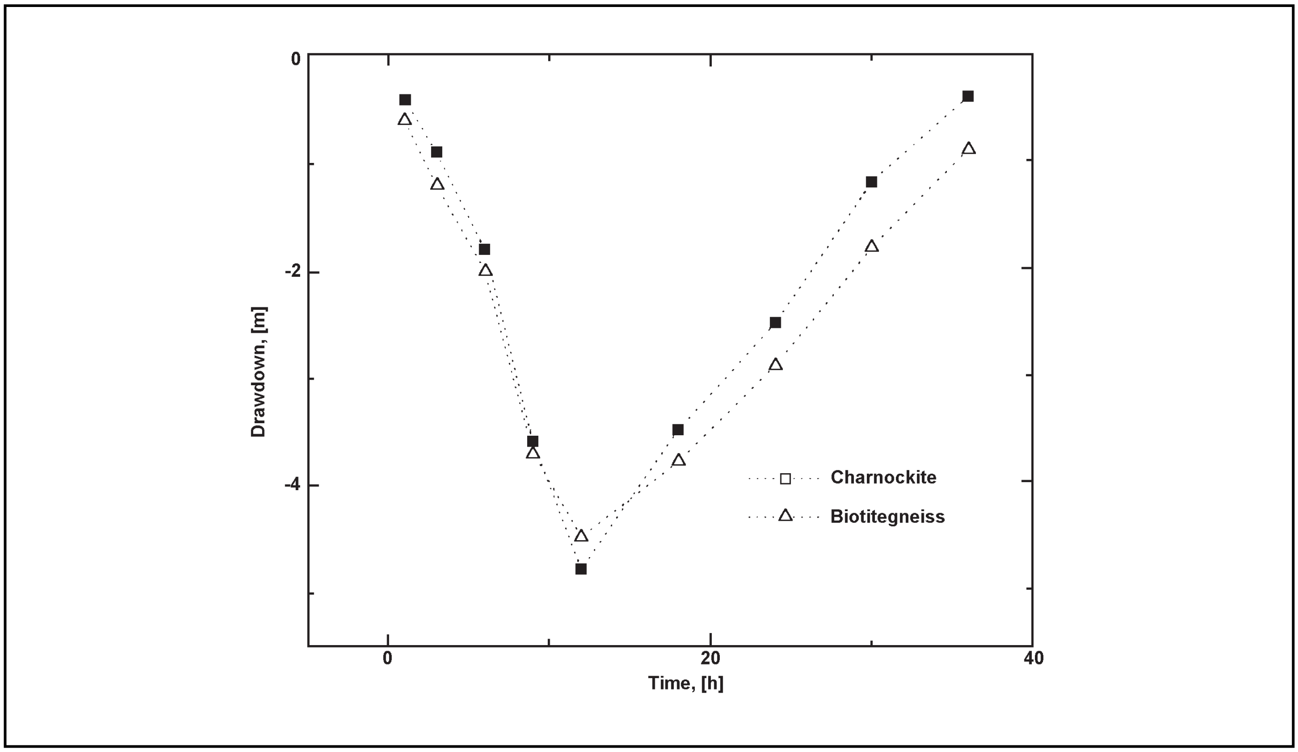

Figure 5. Daily drawdown and recovery of water level in agrowells in the lower region.

higher in agrowells in biotitegneiss. Table 1, based on information from the owners of agrowells, shows that those in biotitegneiss take about two days to recover, and drawdown is vice versa. The same can be seen on Figure 7. The fluctuation of water level is same in both charnockite and biotitegneiss (4 m). The same deformation, fracture intensity, and joint pattern and similar overburden conditions exist in both rock types, which may explain the same drawdown and recovery.

Table 1. Hydrogeological data of agrowells

Rock type	No. of Wells	Average depth (m)	Water level in rainy and dry seasons (m)		Total Draw down after each day pumping (m)	Time taken for 100% Recovery (days)
			Rainy	Dry		
Uppercatchment						
Charnockite	6	8.0	G.L	3.0	0.7	1
Bt. gneiss	6	7.0	G.L.	5.0	0.5	1
Granulite	8	7.5	G.L.	6.5	1.0	2
Quartzite	3	7.0	G.L.	7.0	1.0	2
Middlecatchment						
Bt. gneiss	19	8.0	G.L.	4.0	0.8	2
Charnockite	17	7.5	G.L.	4.0	1.2	1
Lowercatchment						
Bt. gneiss	8	8.5	G.L.	1.5	0.7	1
Charnockite	12	7.5	G.L.	2.0	0.7	1

Agrowells in the lower catchment region

About 27 percent of agrowells were investigated in the lower catchment region. Figure 5 shows that the drawdown and recovery are similar on both charnockite and biotitegneiss. Owner information (Table 1) and pumping test data (Figures 5, 6, 7) are the same in this region. Water level fluctuation and drawdown are low and recovery is high (one day for 100 percent recovery) in this region (Table 1 and Figures 6 and 7).

Figure 6 shows a clear picture of drawdown as a function of time in agrowells for different regions and in different rock types. In the upper region, agrowells on quartzite, granulite and charnockite show high drawdown (8 m). Recovery is higher on charnockite (36 h) than other rock types (60 h). Drawdown is the same (6 m) in agrowells on biotitegneiss in the upper and middle regions. The agrowells on charnockite and biotitegneiss in the lower region have the lowest (4-5 m) drawdown and the highest recovery.

Figure 7 shows the average water level fluctuation as a function of agrowells in different regions on different rock types during the rainy and dry seasons. Agrowells on quartzite in upper region have the highest fluctuation (8 m). The fluctuation decreases respectively with granulite (7.5 m), biotitegneiss (5 m) and charnockite (3 m). The fluctuation on charnockite in the middle region (4 m) is higher than in charnockite in the upper region (3 m).

Figure 8 shows that there is a gradual increase in the seasonal fluctuation of groundwater level from lower to upper, and the lowest water level fluctuation is shown in wells in close proximity to irrigation reservoirs and channels.

Figure 9 shows a quick response of the water level of agrowells to rainfall. In the vast majority, water level starts to rise immediately after the first rains of the rainy season.

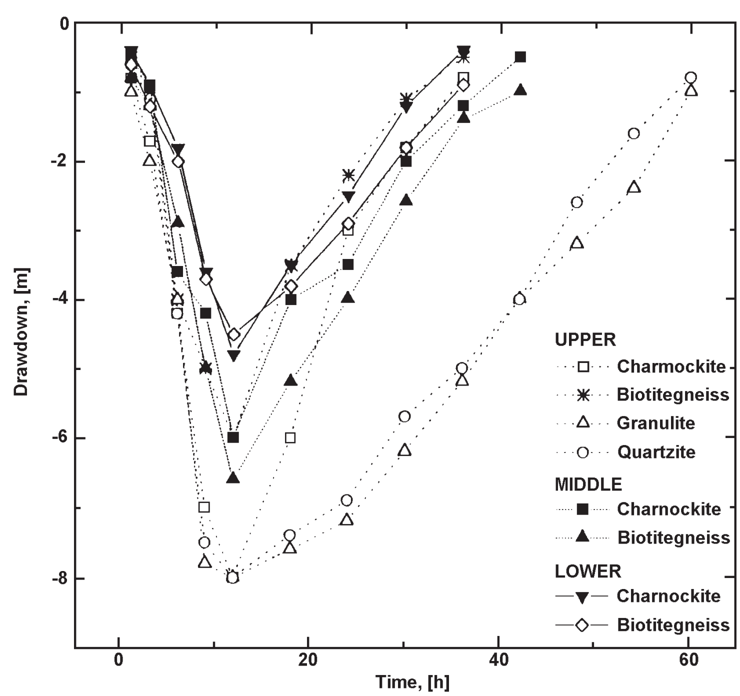

Figure 6. Daily drawdown and recovery of water level in agrowells in different regions with different rock types.

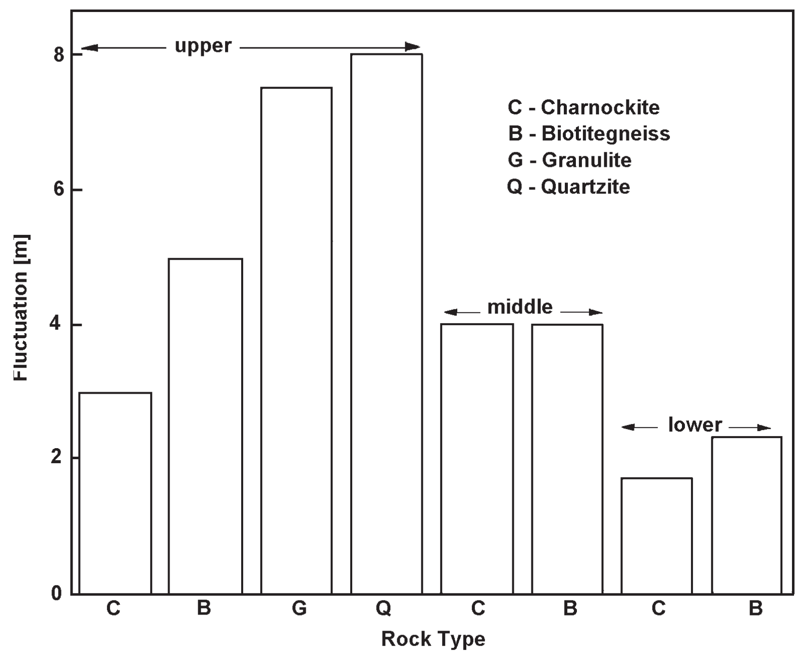

Figure 7. Average annual water level fluctuation in agrowells in different regions, with different rock types.

Agrowells close to irrigation reservoirs or channels

About 33 percent of the agrowells are located close to irrigation reservoirs or channels. All hydrogeological parameters such as water level fluctuation, drawdown, recovery and recharge is

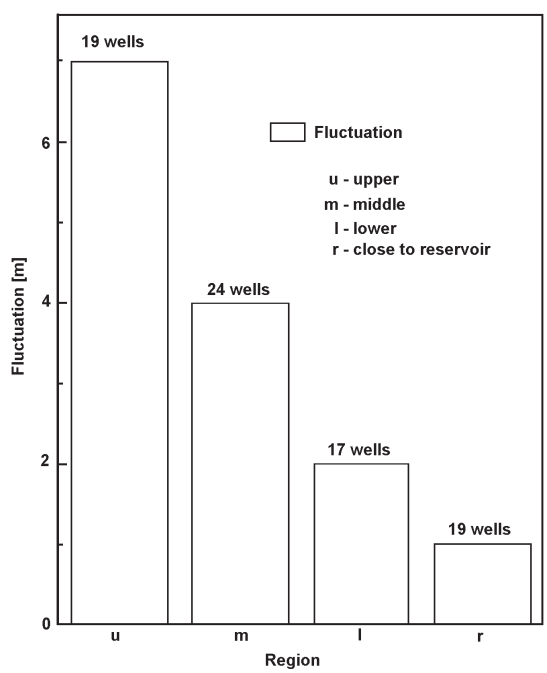

Figure 8. Average annual water level fluctuation in agrowells in different regions of the basin.

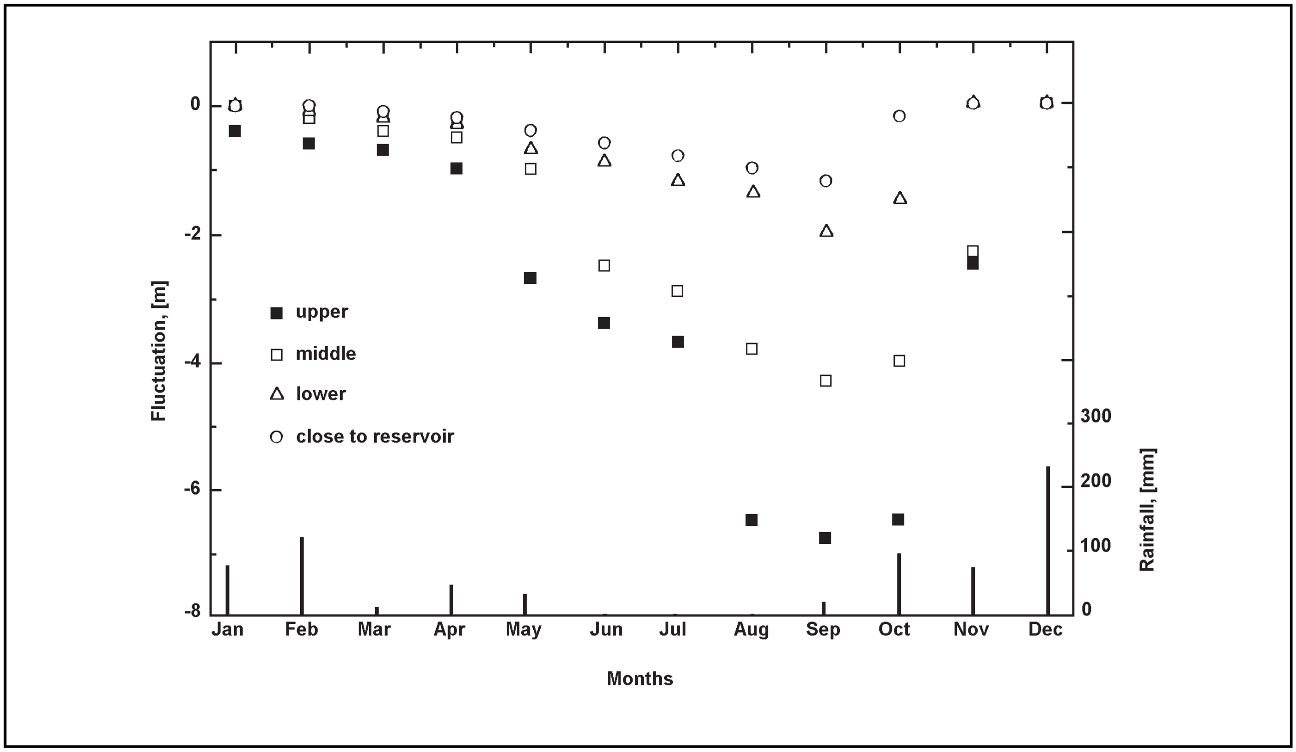

Figure 9. Average monthly rainfall (mm) 1994/95 and monthly groundwater level fluctuation in different regions of the basin.

maintained mostly by direct influence of irrigation reservoirs, and frequently from water flow of irrigation channels. Generally, in the rainy season (“Maha”), the farmers use both rainwater and irrigation reservoirs. Agrowells are seldom utilized. However, during the dry season (“Yala”), farmers use agrowells to cultivate short-term crops. Groundwater levels of agrowells close to irrigation channels are stable. The fluctuation is very small (0.1 - 0.3 m). Most of the time pumping drawdown is zero.

According to agrowell inspection data sheets, well construction has also tended to directly maintain the drawdown, recovery and recharge of groundwater in agrowells.

CONCLUSIONS

It was found that the best performance of agrowells is close to irrigation reservoirs. However, we recommend the construction of agrowells around irrigation reservoirs be controlled since water in reservoirs can directly seep to agrowells, damaging irrigation systems.

Agrowells in the lower catchment show good performance without apparent influence of rock types, both in the dry and rainy seasons. Construction of agrowells in the lower region could increase, provided that a proper investigation is carried out for optimum utilization of water. According to agrowell inspection data sheets, there should be 300 m minimum distance between agrowells to minimize interference during pumping. Over extraction of water and over construction of agrowells in the lower region may decrease the water levels of the upper and middle regions.

Agrowells in the upper and middle regions show different performance according to rock type. Agrowell inspection data sheets indicate that agrowells on thick soils, in valleys, and in fractured zones show good performance. Before construction of agrowells in these regions, a proper geophysical investigation, in addition to conventional geophysical and structural interpretation of topographic maps and aerial photographs, should be conducted.

Pumping tests were conducted during the intermediate season (April - June), between the "Yala" and the "Maha". If conducted during the dry or rainy seasons, values could change in different regions and on different rock types.

The agrowell programme started nine to ten years ago. Now is the time to conduct a proper study on the impact of agrowells on the groundwater system, including possible environmental impacts due to over exploitation of groundwater extracted from agrowells (especially in the Anuradhapura district) before starting a large scale agrowell programme. For such a study, a continuous monitoring programme as well as an agrowell awareness information campaign is needed.

ACKNOWLEDGMENTS

Our thanks are due to Mr. Asoka Perera, Manager of Studies, Groundwater Section, National Water Supply and Drainage Board, for assistance during this study, and to Dr. S.V.R. Weerasooriya for his kind assistance in preparation of this paper. Thanks also to Mr. Rohan Perera and Ms. Jayanthi Wijesekera for their help in preparing the figures.

REFERENCES

Cooray, P.G.; (1984). An introduction to geology of Sri Lanka. 114 pp.

Dissanayake, C.B.; (1989). Deep wells and rural development, Journal of the Geological Society of Sri Lanka, Vol.2, printed in Sri Lanka.

Dissanayake, C.B.; (1992). A decade of hydrogeological contributions to community development in Sri Lanka. Journal of the Geological Society of Sri Lanka, Vol. 4, pp 3-10. printed in Sri Lanka.

Dharmasena, P.B.; (1995) Integrated water resource management approach for efficient use of shallow groundwater. Concept paper submitted to SCOR project (Huruluwewa watershed), IIMI, Colombo.

Dharmasena, P.B.; (1995). Half recovery time: An indicator for well water availability, Proc. of the 50th annual session of Sri Lanka Association for the Advancement of Science , 1995. Part 1 : pp 99-100.

Groundwater monitoring programme status report. April 1995 (National Water Supply and Drainage Board, Groundwater Section, Anuradhapura, Unpublished.)

Groundwater depletion in Anuradhapura district.; (1993). (National Water Supply and Drainage Board, Groundwater Section Anuradhapura, Unpublished)

Lawrence, A.R. and H.A. Dharmagunawardhane; (1983). Vertical recharge to a continued Limestone in northwest Sri Lanka. Journal of Hydrogeology 63, pp 287-297.

Wickramaratne, H.U.S.; (1996). Hydrogeological and hydrogeochemical behaviors of agrowells in Kalaoya basin, Anuradhapura district. (unpublished, B.Sc. thesis.)

Wickramaratne, H.U.S. and H.A. Dharmagunawardhane; (1998). Use of agrowells for small scale irrigation and their effect on groundwater system in a hard rock aquifer: A case study in Kalaoya basin, Sri Lanka, Journal of Geoscientific Research in Northeast Asia, Vol.1, 52 pp. (Future Groundwater Resources at Risk Abstract Volume).

ADDRESS FOR CORRESPONDENCE
H. U. S. Wickramaratne
Environmental Modeling Program
Department of Earth Sciences
Institute of Fundamental Studies
Hantana Road
Kandi
Sri Lanka