A STATISTICAL APPROACH TO STUDY THE OPTIMUM DRILLING DEPTH IN PATHADUMBARA AREA

By

U. de S. Jayawardena

1.0 Introduction

1.1 General

Kandy District Water Supply and Sanitation Project was commenced under the consultancy services of the Government of Finland and Government of Sri Lanka in 1981. Since 1987 October this project was managed by SOIL AND WATER LIMITED, Finland.

One major objective of this project is to improve the quality and quantity of drinking water and to make supplies accessible to the entire population. The rehabilitation of existing piped water supply schemes and establishment of new piped water supply schemes by using groundwater from deep wells is one implementation in areas with high housing densities. Construction of deep wells and equipping them with hand pumps is to other implementation to supply groundwater in sparsely populated rural areas out side the reach of piped water supply schemes.

Detailed hydrogeological investigations have been carried out to examine the possibilities of locating dependable groundwater sources and to obtain sufficient information on groundwater availabilities in many areas within the Kandy district. Test pumping, water sampling and analysis have been carried out fr evaluation of the quantity and quality of water available in the wells. Borehole reports were made to describe the subsurface situation of each well. A regional study on the occurrence of groundwater can be done using these available data. Hydrogeological bedrock study can be done by analysing the borehole reports in any region. Further information can be taken by doing borehole geophysics. This study is mainly based on the detail information of the borehole reports from Pathadumbara A.G.A.'s division.

1.2 Objective

The purpose of the study is to identify the fracture levels of bedrock and to find the most economical (maximum) drilling depth to get a sufficient groundwater yield.

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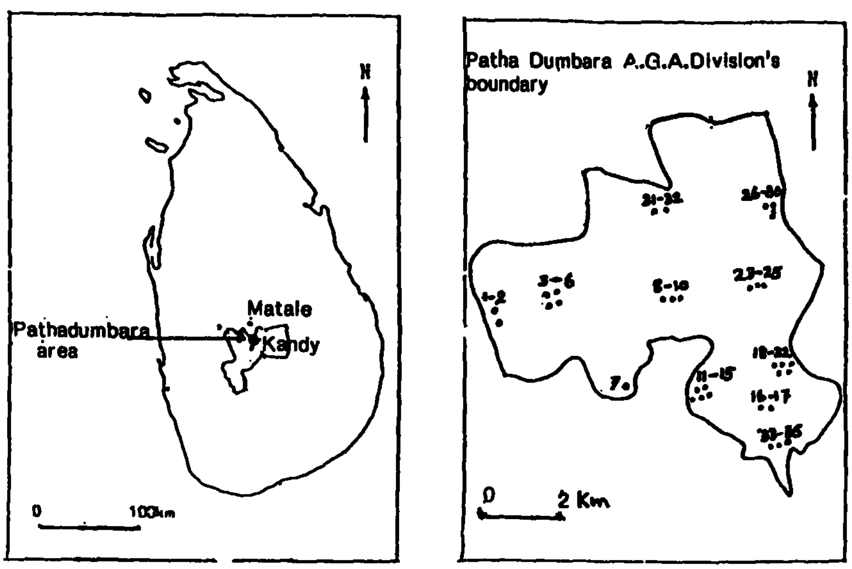

Fig.1 Locations of borehole wells constructed in Patha Dumbara area.

2.0 The Project

2.1 The area

Pathadumbara is one of the Assistant Government Agent divisions in Kandy district (Fig.1.). The project area covers nearly 46.2 square kilometers. The projected population for the year 2010 will be 92,000 and the estimated water demand for the project area is about 10,000 cubic meters per day (PLANCENTER Ltd, 1981). The project area consists of dome shaped ridges, escarpments and valleys with gentle slopes where the elevation varies from 440 meter to 760 meter above the mean sea level. The valleys are flood-planes of Mahaweli river, Pinga Oya, Ravan Oya and Pussalu Oya. The upper part of the soil cover is composed mainly of dark brown clayey soil and the lower part consists of partly weathered bed rock.

The project area belongs to the Wet Zone of the Island. The mean annual rainfall is about 1940mm (1981-1988) and the average temperature varies from 20-26 C during the year. The project area is situated in the northern half of the catchment of Polgolla reservoir which was constructed by damming the Mahaweli river at Polgolla.

2.2 Geology

The area is underlain by precambrian metamorphic rocks of the Highland Series such as biotite gneiss, hornblende biotite gneiss, charnockite, quartzite, granulitic gneiss, migmatite and garnet sillimanite gneiss. The structural setting and the trend lines of the country rocks exhibit a good morphotectonic relationship to topographical features in the project area. The general strike of most of rocks shows 325 direction and having dips ranging from 60-80. Two sets of major lineament patterns exist along 45 and 135 directions. Hydrogeologically in the project area, deep groundwater may occur only under favourable structural condition specially along the rock contacts, rock joints or other types of fractures of the country rocks (SOIL & WATER Ltd., 1990).

2.3 Construction of borehole wells

Site selections for borehole drilling have been done based on air photo interpretation, morphological and structural condition and evaluating the available data. Based on the above investigations the drilling operations have been conducted using DTH drilling rigs and compressed air. Casings have been installed only above the bedrock level to the ground surface for all deep wells to prevent the collapsing of soil overburden. The crushed rock samples have been taken during drilling for every one meter depth and the flushing yields have been measured with the penetration depths. All the boreholes have been flushed and cleaned after completion of drilling and then the final flushing yields were measured. Borehole reports have been made for each well.

3.0 Method of Study

3.1 Data collection

The borehole reports and the location maps of all borehole wells were collected to study the subsurface fracture systems of the crystalline hard rocks in the Pathadumbara area. This study is based on the borehole reports of each drilled well and all of them have been categorized as production wells.

3.2 Method of analysis

The major information that could be taken from the borehole reports were subsurface rock types, penetration rates of rock drilling and the groundwater discharges at various depths. From all of these data only the flushing yields at various depths were considered for determining the subsurface fracture patterns. If there is a fracture in the solid bedrock which has a very low permeability, a groundwater flow can be expected through it when the terrain is wet. Under this assumption the number of fractures can be counted by observing the changes of the flushing yields from the surface level to the bottom of the well. If the fracture intensity through such zones if those are well interconnected. Therefore the flows of groundwater at various depths can be used to detect the fractured levels and their general occurrence within the region.

In order to find the fracture intensity the flushing yields and the relevant depths of each well were obtained from the borehole reports. The noted flushing yields of each 5 meter depth from all the wells were counted and the average found by dividing the total number of wells (32). Table 1 indicates all the information about the flushing yields. The variable yields with the depths were used to draw histograms and frequency polygons (Fig.2 and Fig.3).

As mentioned earlier, if there is a groundwater flow through the bedrock at any depth it is an indication a fracture. To find the total number of fractures in any well of the levels where the groundwater was flowing into the well were noted. Then the number of fractures and the relevant depths of the well were found. This method was carried out for all the production wells in the Pathadumbara area. The total number of fractures in every five meter depths were counted. Table 2 shows the number of fractures in each 5 meter and the percentage of the rock fractures at various depths. This variation was used as a frequency dis-

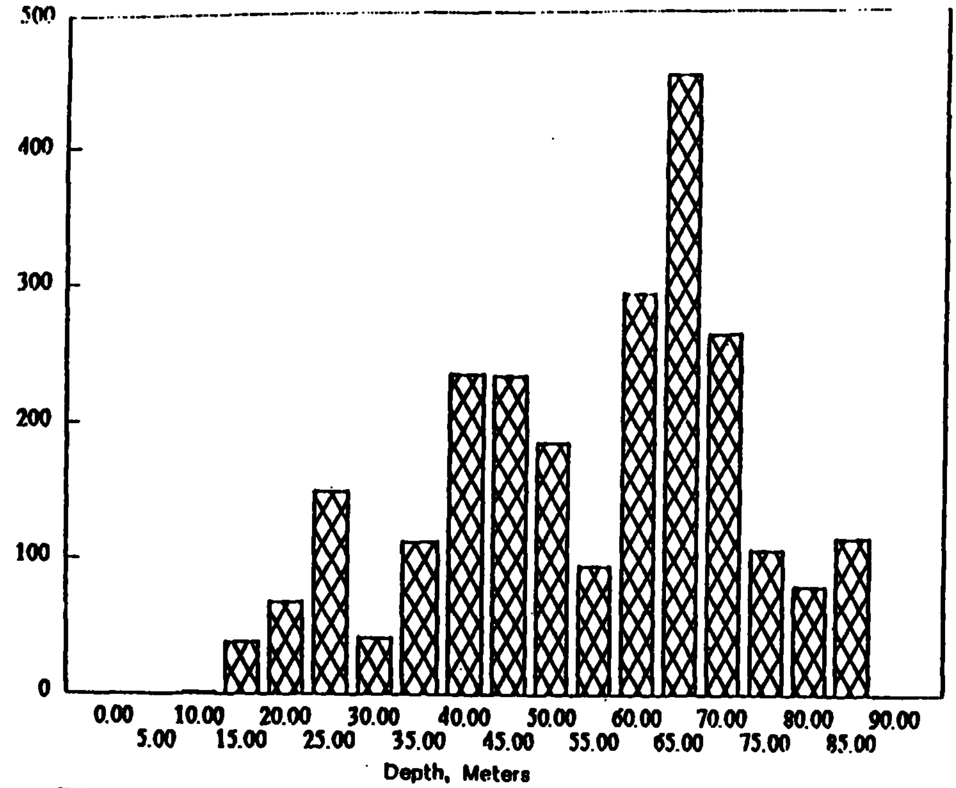

Fig.2 The average flushing yield of each five meter depth from the ground surface.

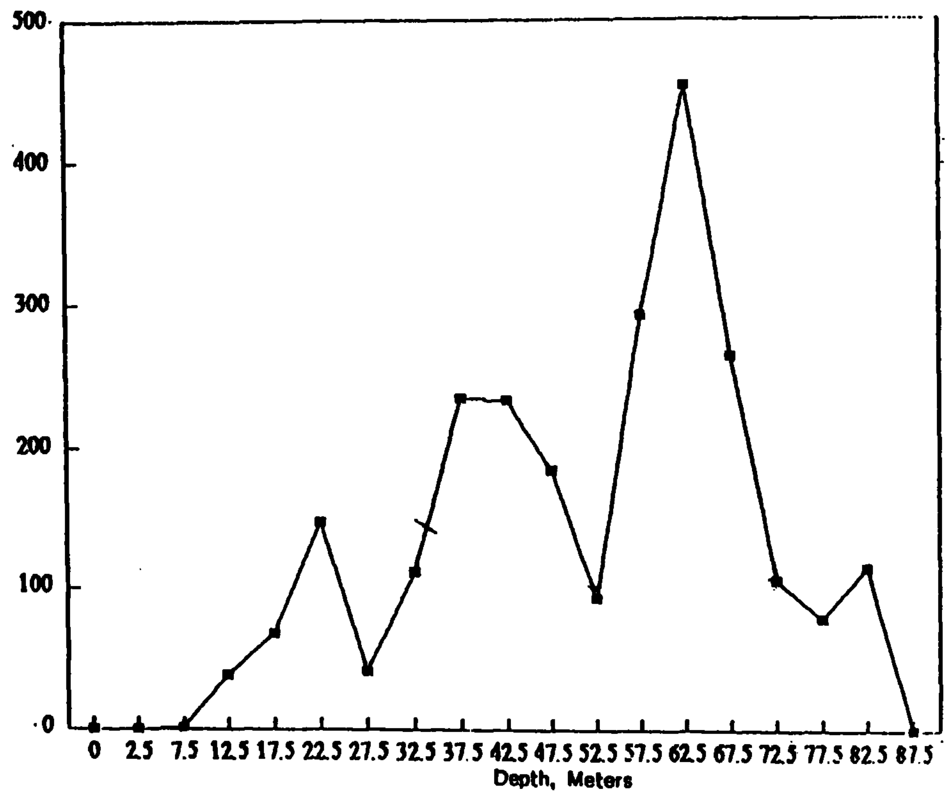

Fig.3 The frequency polygon of the average flushing yield of each five meter depth.

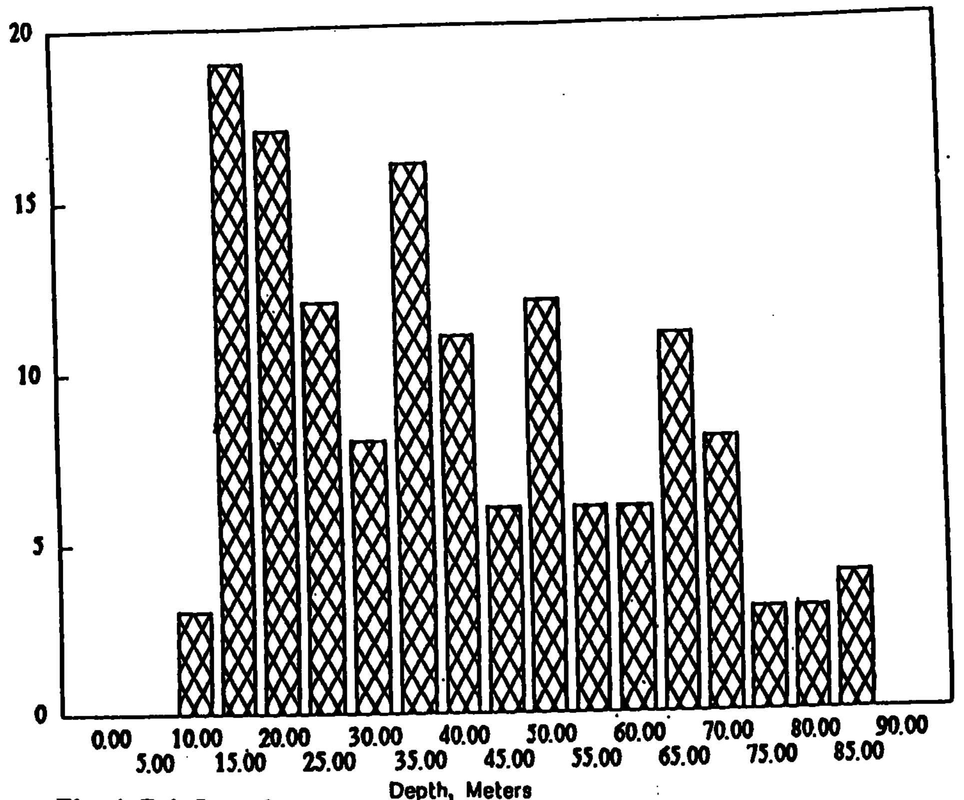

Fig.4 Total number of fractures in each five meter depth below the ground surface.

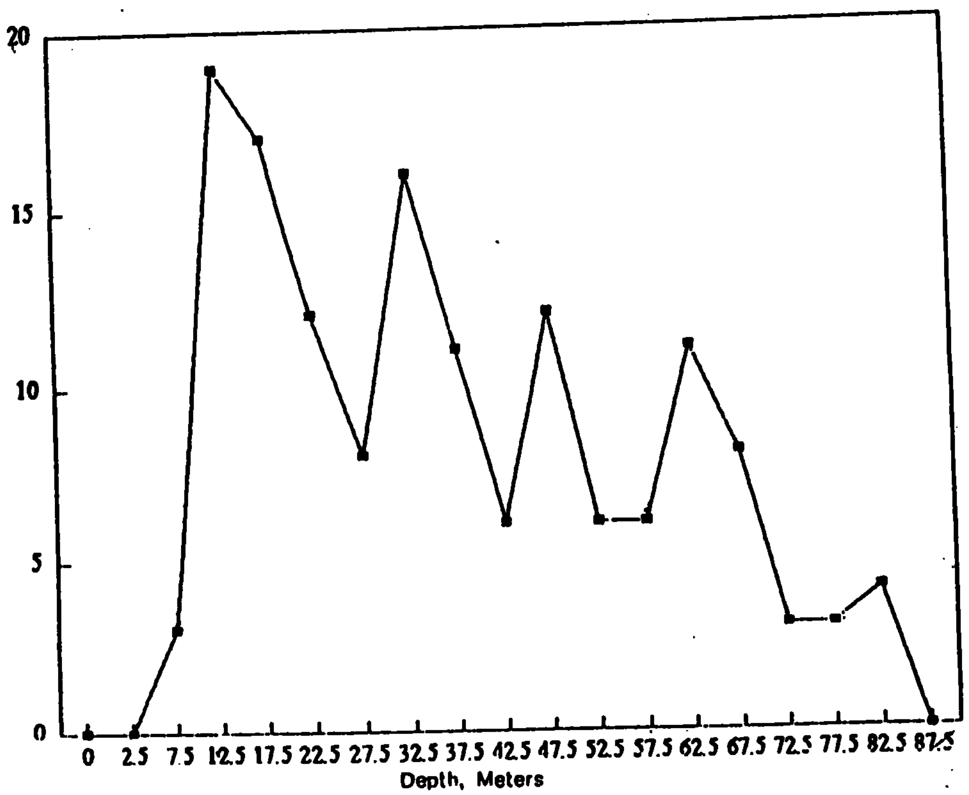

Fig.5 The frequency polygon of the total number of fractures in each five meter depth.

tribution table for fractures in the bedrock upto the depth of 90 meters, the total depth of wells. Using this data histograms and frequency polygons were drawn to show the total distribution of fractures in the studied area (Fig.4 and Fig. 5).

4.0 Results and Discussion

In general the sites have been selected in the low elevation, valleys and flood plains within the project area. The exact elevation of the wells at the ground surface have not been measured. Therefore the actual levels of the fractured rocks cannot be calculated. However the general elevation or the closest 25 meter contour lines are given in Table 3. It shows the ground surface levels of the well sites occur between 425 m and 500 m, MSL.

The histograms of the average flushing yields (Fig.2) shows their variation with

the depth. Accordingly, higher flushing yields can be expected from three levels as given below.

Depth	Higher flushing yield
20-25 meters	150 1/min
35-40	240
60-65	450

The maximum water yields upto 25 meter depth is 150 1/min and upto 50 meter, 240 1/min. At 65 meter depth it is the highest yield 450 1/min and then the yield is decreasing drastically (Fig.2 and Fig.3). No more water flow could be recorded at 85-90m depths.

In general a yield of 250 1/min well can be recommended as a good production well. Out of 32 wells only 8 wells supplied higher yields between 80-85 meters. To obtain such a capacity from a well, the minimum drilling depth should be 65 meters. Beyond 70 meter depth the water flow is comparatively very low. It indicates that drilling more than 70 meters is a loss and the cost/benefit ratio goes up. Therefore the maximum drilling depth should not be beyond 70 meters from the surface level.

Fig. 4 and Fig. 5 indicate the distribution of rock fractures upto 90 meter below the ground surface. It clearly indicates that the fracture intensity is very high close to the ground surface and gradually decreases with the depth. In general, close to the surface more weathering and more openings in the rock materials could be expected and therefore water may flow through these fractured rocks. The number of fractures were higher at the levels of 10-15m, 30-35m,

45-50m and 60-65 meters than at the other depths relatively. Though there are higher number of fractures at the shallower depths the water flow through these areas are low. In other words, more water could be obtained from the deeper areas through less number of fractures. But the thickness of the fractures may vary which is not so easy to detect by this method. Below 70 meter level the number of fractures is very low. According to Table 2 at 70 meter more than 93% of rock fractures have been recorded. Comparatively between 60-65m levels higher flushing yields could be obtained (Table 1). This indicates that groundwater circulation in this levels is higher because fractures are well interconnected with a good source.

Depth meters	Total Flushing Yield 1/min(32 wells)	Average Flushing Yield 1/min	Yield below 250 1/min number of times	Yield above 250 1/min number of times	Probability of getting over 250 1/min
00-05	00	00	00	00	00
05-10	54	1.68	03	00	00
10-15	1202	37.56	18	01	1.3%
15-20	2181	68.15	13	04	6.5%
20-25	4727	147.7	07	05	13%
25-30	1330	41.56	05	03	16.9%
30-35	3563	111.34	12	04	22%
35-40	7528	235.25	05	06	29.9%
40-45	7467	233.34	01	05	36.4%
45-50	5874	183.56	03	09	48.1%
50-55	3013	94.15	01	05	54.5%
55-60	9398	293.68	00	06	62.3%
60-65	14484	452.62	00	11	76.6%
65-70	8470	264.68	00	08	87%
70-75	3391	105.96	00	03	91%
75-80	2534	79.18	00	03	94.8%
80-85	3667	114.59	00	04	100%
85-90	00	00	00	00	100%
TOTAL			68	77	

Table 1. The variation of flushing yields with depth and other relevant statistical informations.

Depth meters	Number of fractures	Fracture Intensity as percentage	Probability of getting over 250 l/min (from Table 1)
00-05	00		0.0
05-10	03	2.06%	0.0
10-15	19		1.3%
15-20	17	26.9%	6.5%
20-25	12		13%
25-30	08	40.7%	16.9%
30-35	16		22.1%
35-40	11	59.3%	29.9%
40-45	06		36.4%
45-50	12	71.7%	48.1%
50-55	06		54.5%
55-60	06	80%	62.3%
60-65	11		76.6%
65-70	08	93.1%	87%
70-75	03		91%
75-80	03	97.2%	94.8%
80-85	04		100%
85-90	00	100%	100%
TOTAL	145	100%	

Table 2. The variation of fracture intensity with depth vertically through the bedrock.

Well Nos.	Mean Sea Levels,
8005, 8006	450-475 meters
2112, 2113, 2114, 2115,	< 450
2118	< 450
2106, 2107, 2108	< 450
2165,2166,2167,2168,2169	450-475
2100, 2120	< 450
2101,2130,2131,2174,2175	< 500
2135,2136,2137,2138,2139,2140	450-475
2102,2121,2123,2133,2134	450-475
2127, 2128	500-525
2124, 2125	500

Table 3. The general elevation of well sites or the closest contour lines.

However the results were obtained without considering the surface elevations of each well. As mentioned earlier, all the wells are located in the lower elevations, valleys and flood plains. Generally the geomorphological features are also related to the geological structures and the fracture systems of bedrock. The lower elevations normally follow the weak zones. This analysis indicates that there should be a relationship between the levels of the subsurface fractures and the surface levels because all wells have been constructed along the regional fracture zones. (Table 3)

5.0 Conclusions and Recommendations

The flushing yields are higher between 60-65m depth and the average is above 250 1/min at that depth. Beyond 70 meters of drilling the average yield decreases. The possibility of getting flushing yields of more than 250 1/min up to 70 meters of drilling is high and it is about 87%.

The fracture intensity at shallow depth is very high. About 93% of fractures have been crossed within 70 meter depth. The flushing yields are lesser than 250 1/min at very shallow depths where the fracture intensity is very high. This indicates that the shallow fractures are not connected with a groundwater source or aquifer.

This analysis was carried out using only 32 (available) borehole reports. It was found that drilling beyond 70 meters below the surface level would not be beneficial and it may be an unnecessary expense except in a very few locations. This conclusion is valid for the wells to be constructed within this studied area only. Also, the well sites should be selected only in the basins or valleys.

A general conclusion cannot be made through this study because the movement of groundwater is depend on the particular terrain and the geological conditions. But the maximum drilling depth for groundwater wells can be estimated by this type of study in any region. The future wells can be drilled accordingly to reduce the cost per well.

6.0 References

PLANCENTER LIMITED, Interim Report of Kandy District Water Resources Potential Study, 1981, Kandy.

SOIL AND WATER LIMITED, Report on the Study of Groundwater Resources in Pathadumbara A.G.A. Division, Kandy District (Analysis and Evaluation of Pumping Test Data), R1-86-00/41, 1990, Kandy.