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Performance Investigation of Existing Tube-wells of Pusa Farm and Estimation of Crop Water Requirements

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Abstract
The underground water level is declining at an alarming rate and it is necessary to improve the performance of submersible pumps. During summer, the water level at different locations in this zone drops below the optimum range of the pump causing a low discharge as well as poor performance of the existing tubewells of the RPCAU, Pusa Farm area. The additional descent of pumping level further deteriorates the working condition. In the present study, the efficiency of all the four existing submersible pumps of the study area was calculated and thereafter total crop water requirements of the farm was estimated. During the study it was found that maximum pumping head in the study area is 27.77m and output power ranges from 5.11 hp to 12.09 hp, the pump discharge varies from 14.50 litres/sec. to 33.23 litres/sec. and maximum and minimum efficiency of the exiting submersible pumps was found 60.45% and 51.04% for pumps installed at Harpur 1-B and Harpur Jhilli-B respectively. Existing four submersible pumps in the study area has been used to irrigate total farm area of 76.80 ha, under different crops. Total crop water requirements for the study area were found 45.3 ha-m. Available amount of water from the existed tubewells for the whole cropping season was also calculated which was 105.5 ha-m. Thus, it is evident that, there is no need to install any extra tubewell in the study area and the crop water requirements will be met from the existing tubewells.

Keywords: Tube-wells, Submersible pump, Pump efficiency, Crop water requirements, Discharge, Pumping head

1. Introduction

Irrigated agriculture makes a major contribution to food security, producing nearly 40 percent of food and agricultural commodities from approximate 270 million ha. of land (Pascale et al. 2011) [2], equivalent to 17 percent (Imtiyaz *et al.*2000) [4] of agricultural land. Irrigated areas have almost doubled in recent decades and have contributed much to the growth in agricultural productivity over the last 50 years. Moreover, FAO (2014) [3] has estimated that irrigated agriculture uses more than 70% of the water withdrawn from the earth's rivers; whereby the proportion exceeds 80% in developing countries. Water is a valuable resource in agricultural food production while it remains a finite resource, the competition of this precious resource is highly increasing due to current and future events such; rapid increase in world population which is expected to reach 9 Billion by 2050 (FAO, 2014) [3]. This possesses a threat to sustainable agricultural production and global food security; due to unsustainable agricultural practices that require excessive water and other production inputs leading to inefficient production and water scarcity (Costa *et al*. 2007) [1]. In the planning and management of available water resources for the agriculture sector, the defining strategies become a national and global priority. The effective use of water both in irrigated and rainfed area for crop production is one of the main requirements. The rise in water demand for agriculture, industry, domestic, and environmental needs require the use of this limited natural resource sagaciously. Since agriculture is the major use of water, so improving agricultural water management is very essential.

The estimation of water requirements of the crop is essential for crop planning on a farm and also it is the basis on which an irrigation project is designed. The increasing demand and scarcity of water make it important to use the available water in the most economical way. Management practices for conservation of water have been increasingly emphasized because of sparse natural precipitation, high evapotranspiration and excessive depletion of limited groundwater resources. Higher crop productivity can also be attained by proper soil, water and crop management in the area with assured irrigation.

The submersible pump is multi-stage pump where all the impellers are mounted on a single shaft and all rotate at the same speed. Each impeller passes the water to the eye of the next impeller through a diffuser. The diffuser is shaped to slow down the flow of water and convert velocity to pressure. So, it can develop more lifting of water without any cavitation. Each time water is pumped from one impeller to the next, its pressure is increased. As the ground water level is declining day by day, it is almost impossible to lift water by low lift pump like centrifugal pump for irrigation, drinking and industrial purposes today. It has become urgent to lift water by high lift pump like submersible pump for irrigation and other purposes. During the summer season, the water level goes down. It is generally caused when the ground water heads in an aquifer fall below a critical or threshold level over a certain period of time due to natural or human induced cause and interventions. As a result, the performance of submersible pump drops. It is reported that about 10% to 30% of the energy consumed by submersible pump could be saved through the change of way of operation and control system (Haque *et al*. 2015) [6]. The factor well drawdown is mainly responsible for shifting the pumping head from the operating range. Drawdown of a submersible pump depends on well bore diameter and well screening. Main objectives of the present work are to investigate these factors that controlling the efficiency of the pumps and to observe pump performance under different operating conditions.

2. Methodology

The study was carried out for RPCAU, Pusa Farm located in the Samastipur district of North Bihar. The ultimate aim of this study is to calculate the water requirements in irrigation operation for major irrigated crops of Pusa Farm for the year 2017-18 and efficiency of existing tubewells in this farm.

The pumping water level of a pump was measured manually with the help of string, stud and tape. First, static water level of pump was measured before operating the pump with the help of string and stud. The static head was measured by lowering a stud and noting the points up to which it had been wetted. Pump operating for 3-4 hours continuously thereafter pumping water level was observed with same procedure. An ordinary cylindrical container of 200 *litre* (diameter: 53 cm and height: 89 cm) was used in the measurement of discharge of each existing tubewell. The total pumping head required to estimate the efficiency of tube well which is a function of water table depth below ground surface, drawdown in the well, friction losses in pipes and fitting and delivery head. Total pumping head can be expressed as:

$$H_p = H_2 + K\frac{v_2^2}{2g} + \frac{p_2}{\rho g} \quad \text{... (1)}$$

Where,

$$K = \{1 - \left(\frac{d_2}{d_1}\right)^4 + f_{ls} + f_m\frac{L}{d_2} + f_{lb} + nf_{lf} + f_{lo}\}$$

K is a constant for each tubewells which depends on d_1, d_2, L and coefficient of losses (Michael, 2010) [5].

Total losses are the energy required to overcome the resistance of the pipeline and fittings in the pumping system. In present study the frictional losses were calculated using Bernoulli's equation.

Applying Bernoulli's equation taking account the head loss between point 1 and point 2, **(Fig.1)**

$$y_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + H_p = y_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_{ls} + h_{lv} + n \times h_{lf} + h_{lo} \quad \text{...(2)}$$

For datum line (point 1),

$y_1=0$; $p_1=\rho g H_1$

For outlet point (point 2.)

$$y_2=H_1 + H_2;\ V_1=\left(\frac{d_2}{d_1}\right)^2 V_2;\ h_{ls}= f_{ls}\frac{v_2^2}{2g};\ h_{fm}= f_m\frac{L}{d_2}\frac{v_2^2}{2g};$$

$$h_{lb}= f_{lb}\frac{v_2^2}{2g};\ h_{lf}= f_{lf}\frac{v_2^2}{2g};\ h_{lo}= f_{lo}\frac{v_2^2}{2g};$$

Where, d1 is diameter of the well, m; d2 is diameter of the discharge pipe, m; P_1 is the suction pressure at datum line, N/m^2; P_2 is the delivery pressure in water distribution line, N/m^2; h_{fm} is the major head loss due to friction in the discharge pipe of diameter d_2, m; h_{ls} is the head loss at pump inlet including effect of screen, m; h_{lb} is the head loss at the bend, m; h_{lf} is the head loss in flange joints, m; n is the number of flange joints.

Pump efficiency is defined as the ratio of energy output to energy input. Pump efficiency vary as a function of the pump type, rate of pumping, head and total losses. Although a good pump can have efficiency as high as 75 percent, most pumps have a much lower efficiency due to variable operating conditions in the field (Khepar *et al.*, 1982). In present study, efficiency of existing submersible pumps at different locations in Pusa Farm area has been calculated from the following relationship:

$$\eta_p = \frac{Q x H_p x \gamma}{360 x P} \quad \text{... (3)}$$

Where, η_p is the pump Efficiency%; Q is the discharge, m^3/hr; H_p is total pumping head, m; γ is specific weight of water, kN/m^3; P is electricity Consumption, kW.

Total Crop Water Requirements of the study area irrigated by existing tubewells was calculated by the following equation:

$$Q = \frac{10A}{\eta_a \times \eta_c}[\{1 - \frac{1}{K_y}(1 - \frac{Y_a}{Y_m})\}ET_m - ER + \sum_{i=1}^{3} W_i] \quad \text{...(4)}$$

Where, Q is the otal amount of water required, m^3; A is crop Irrigated area, ha; ER is monthly effective rainfall, mm; ET_m is the total crop evapotranspiration, mm; Y_a is actual crop yield, ton/ha; Y_m is maximum potential crop yield at ET_m, ton/ha; K_y is crop yield response factor; η_a is water application efficiency%; η_c is water conveyance efficiency,%;

3. Result and Discussions

3.1 Determination of efficiencies of the existing tubewells

Pumping head at different locations for existing tubewells in the study area was measured with the help of string, stud and measuring tape. The measured values of pumping heads and the corresponding calculated discharge values of all the four existing tubewells have been presented in Table 1. Total pumping losses for existing submersible pumps ware calculated with the help of head loss coefficient at pump inlet including effect of screen**(f_{ls})**, head loss coefficient due to friction in discharge pipe (f_m**)**, head loss coefficient at the bend (f_{lb}), and head loss coefficient in flange joints (f_{lf}) etc. (Table 2). The efficiency of existing submersible pumps installed at different locations in the study area was calculated by using equation (3) and has been presented in Table 1. It is clear from table 1 that the maximum pumping head in the study area is 27.77m and output power ranges from 5.11 hp to 12.09hp. The pumps discharge varies from14.50 litres /sec to 33.23 litres/sec. The maximum and minimum pump efficiencies were found 60.45% and 51.04% respectively for pumps installed at Harpur 1-B and Harpur Jhilli B.

3.2 Total crop water requirements

Existing tubewells in the study areas have been used to irrigate total 76.80 ha area under different selected crops during the season 2017-18. Total crop water requirements for this area was calculated by using the equation (4) and was found 45.3 ha-m water for the entire cropping season. Available amount of water from all the four existed submersible pumps was also calculated and was found 105.5 ha-m. The crop water requirement during Kharif was 59% of the annual requirements. Month wise total water available and total crop water requirement for irrigated crops at each location in the Pusa Farm has been shown in Fig 2. From this figures it is evident that at all locations total available water is more than total irrigation requirement for respective cropped areas. Thus, the existing number of tube wells is sufficient to irrigate the Pusa Farm cropped area and there is no need to install any extra tube well.

Table 1: Discharge and efficiencies of existing submersible pumps at different locations in Pusa Farm

Location of pumps	Total head (H_p) (m)	Discharge of the pump (Q) (lps)	Output power (P_o) (hp)	Input power (P_i) (hp)	Pump efficiency (η_p) (%)
Harpur Jhilli A	22.73	19.84	5.93	10	59.32
Harpur Jhilli B	26.77	14.50	5.11	10	51.04
Harpur 1 B	27.76	33.12	12.09	20	60.45
Mansoor Chhawniya	26.84	33.23	11.72	20	58.64

Table 2: Values of total head at different locations of existing pumps of Pusa farm

Name	Pumping head (m)	Velocity at outlet point (m/s)	Pressure head at outlet (m)	Total losses during pumping (m)	Total head (m)
Harpur Jhilli -A	10.01	1.18	12	12.72	22.73
Harpur Jhilli -B	9.40	3.05	12	17.37	26.77
Harpur -1 B	8.07	1.81	18	19.69	27.76
Mansoor Chhawniya	9.13	1.82	15	16.71	26.84

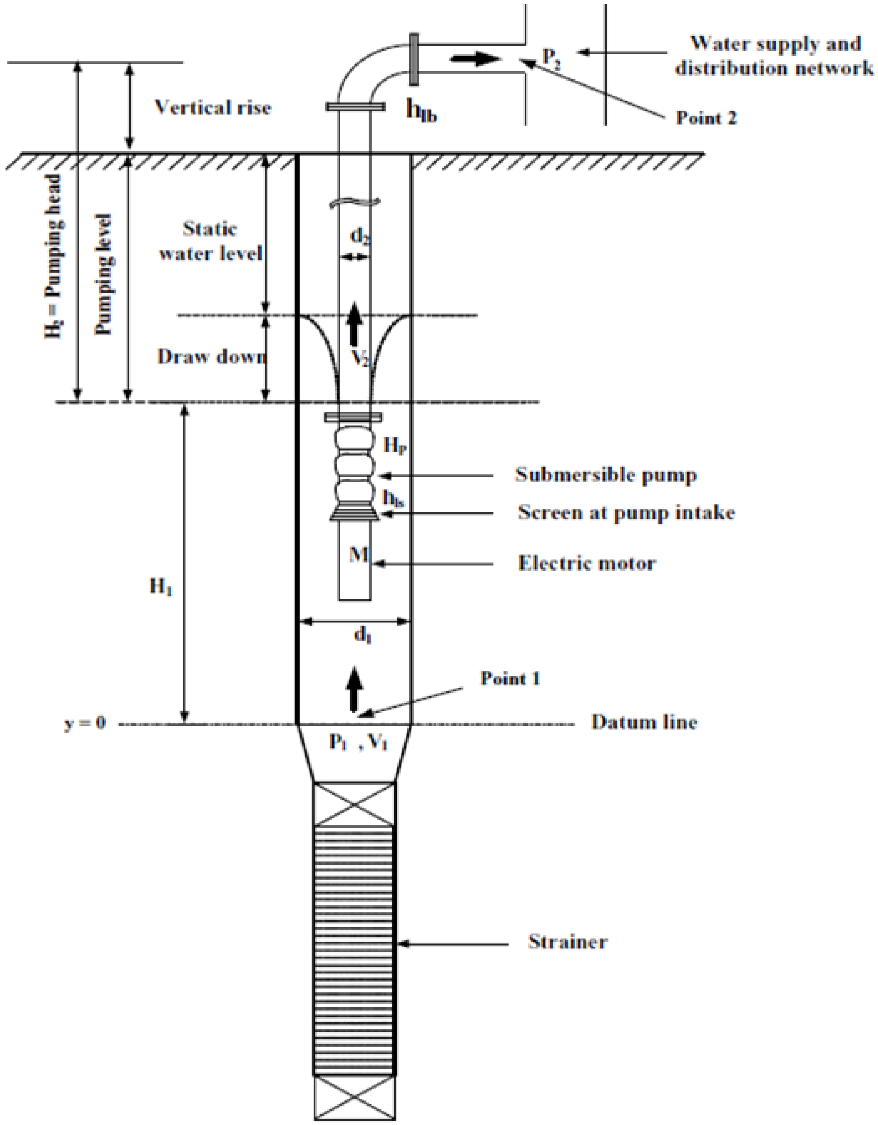

Fig 1: Layout of a submersible pump

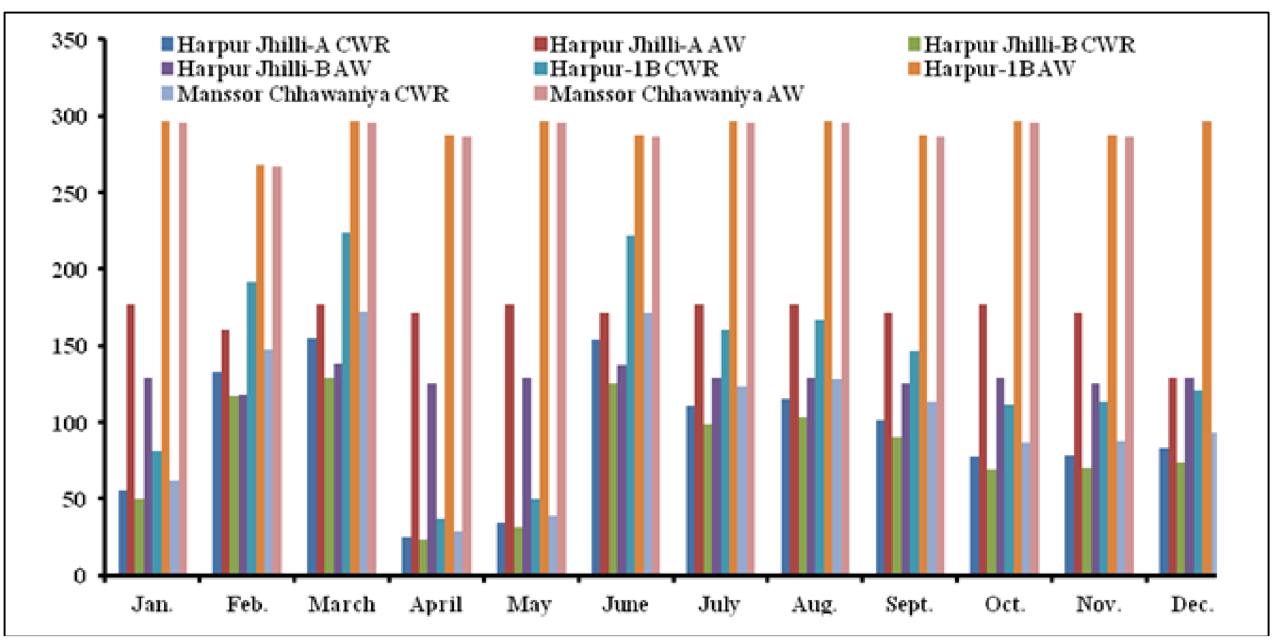

Fig 2: Month-wise crop water requirement (CWR) and available water (AW) (m^3) for cropped area irrigated by tube-well at all the four locations of existing tubewells.

4. Conclusion

Performance of the existing tube wells of the study area was investigated and it has been observed that the annual crop water requirement and available amount of water from all four existing submersible pumps (76.80 ha.) are 45.3 ha-m 105.5 ha-m respectively. The maximum efficiency among existing tube wells was 60.45%, located at Harpur 1B and minimum efficiency of 51.04%, installed at Harpur Jhilli B. It has also been observed from the study that the available water at each location always remains more than the crop water requirement, so it may be concluded that there is no need to install any extra pump in the study area for meeting the required crop water requirements.

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