primary forests are available. The leaves of *Musa nagensium*, a species of banana that was first reported in Nagaland, are used for smoothening wool while weaving. Apart from those used as food and medicine, a good number of plant species are collected as fodder for animals, such as *Spilenthes acmella* and *Ficus obscura*. The women folk play a major part in collecting forest resources; some sell their products in local markets for seasonal income, while some others use them for their daily living. For vegetable vendors NTFPs are the only source of income for their basic necessities such as food, clothing, shelter and education. Some wild fruits that are sold in local markets are *P. cooperiana*, *Canarium strictum* and *Phyllanthus emblica*. Wild vegetables like *Ocimum tenuiflorum* and *Zanthoxylum rhetsum* are also economically important. Young children and women are often seen collecting and selling broom (*Thysanolaena latifolia*), which is also a good source of income. Figure 1 represents some NTFPs used by the Konyak Nagas.

The herbs, shrubs and creepers of medicinal value are diverse and found in abundance, for example, *Houttuynia cordata*, *Centella asiatica*, *Eupatorium adenophorum* and *S. khasianum*. However, with the increase in anthropogenic disturbances, the loss of such species is possible as they are hardly being cultivated. The traditional knowledge on the use of species like *C. urens*, *Gynocardia odorata*, *Entada phaseoloides* and *Hodgsonia heteroclite* needs special attention to be documented, as these are the bioresources that people relied on during famine and food shortage. Less importance has been given to wild edible fruits like *C. strictum* and *Terminalia chebula* because of the lack of knowledge on their nutritive value. A study on nutrient content and health benefits of all these plant species must be incorporated in future research. In a cash-constrained rural economy, with no alternate ways to generate income, there are tendencies of unsustainable harvesting of some species which may be destructive for the forest ecosystem. Therefore, the domestication of commercially important NTFPs is not only important from an economic point of view, but to reduce the threats caused by the increasing demand for forest resources.

Conflict of interest: The authors declare that they have no conflict of interest.

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An empirical method for estimation of groundwater unit draft of energized agricultural tube wells

Indranil Roy

Central Ground Water Board, Mid-Eastern Region,
Patna 800 001, India

Field methods for the estimation of groundwater unit draft are not fully reliable due to non-uniformity of draft in the time domain. In India, use of norm values recommended by the Groundwater Estimation Committee is in common practice. However, large-scale electrification in agricultural sector has drastically changed the agricultural pumping scenario. Conversion of diesel-powered pump sets to unmetered electrified pump sets

e-mail: Indranil_r@yahoo.com

and then to metered electrical pump sets has possibly invalidated the unit draft norms in many parts of the country. In this study, a computational method for groundwater unit draft estimation for energized agricultural tube wells is proposed. Availability of detailed minor irrigation census data is the key towards implementation of the method. The method involves utilization of several well-known empirical formulae for arriving at the desired numerical solution.

Keywords: Agricultural tube wells, groundwater draft, norm values, numerical computational method, unit draft estimation.

GROUNDWATER draft in the broadest sense is the volume of water taken out from an aquifer or groundwater reservoir. Knowledge about draft is vital for formulation of any basin management strategy[1]. In essence, groundwater draft figures are required in all groundwater studies, be it resource assessment, basin management, construction of recharge structure, public water-supply structure or modelling.

The total or gross groundwater draft of an area may be computed by multiplying the number of wells of different types with the unit draft of each well[2,3]. To compute the gross groundwater draft, it is of utmost importance that the unit draft for various types of groundwater abstraction structures is properly computed based on well type, aquifer type, existing hydrogeological condition as well as the prevailing techno-economic situation[1]. Theoretically, unit draft of a well is an estimate of draft from a particular well; however, the well has to be chosen in such a way that it represents the entire study area. It has to be computed for each type of well present in the area, and also has to be computed on daily, monthly and annual basis. These conditions make field study difficult. Hence instead of selecting a single well, several wells are tested and an average is taken. Moreover, though several other field-based methods exist for estimation of unit draft, such as those based on electrical power consumed or on the groundwater irrigated area statistics[4,5], non-uniformity of draft in the spatio-temporal domain makes proper estimation nearly impossible.

Due to these problems, commonly, unit draft is taken according to the norms given by the Groundwater Estimation Committee (GEC) (2015)[3]. These norm values are recommended for groundwater resource estimation in India and they are detailed for different structures as well as for different states[2,3]. A close scrutiny of the norm values, however, reveals that they are the same as those given in the earlier GEC (1985 and 1997) recommendations[2,3]. Therefore, the unit draft values in use today are nearly 35 years old. As groundwater levels are falling throughout the country, and the change in techno-economic situation is leading to conversion of diesel-powered pump sets to electrical pump sets which are capable of pumping more water in less time from deeper borewells, it is possible that the dated values in the groundwater norms, although have been judiciously recommended, do not hold true any more in many parts of the country.

Discharge of an energized pumping well depends on several factors. Among them, water level in the well and capacity of the pump, installed are the most important. In a well, where a pump of a certain capacity is installed, discharge is not uniform throughout the year. In the monsoon season water level will be shallow and discharge will be high, while in the dry season water level will be deeper and discharge low[6]. The pump operator handles the situation by changing the operating hours of the pump. Therefore, theoretical computation of unit draft of an energized tube well/borewell is basically computation of pump discharge with some special conditions. This involves knowledge about pumping schedule, depth-to-water level, capacity of the motor and borehole type.

Data on Minor Irrigation (MI) Census since 1986–87 (when it was first recorded) up to the Fifth MI Census (2013–14)[1] include scheme-wise information (both private and Government) on borehole depth, diameter, average (annual) pumping hours and capacity of the pump installed. If this data are used in conjunction with the prepared depth-to-water level maps of an area, hourly draft of the well can be computed precisely.

With prior knowledge of season-wise operating hours in an area, the hourly draft may be converted to unit draft for any time period. Logbook of any Government-owned MI scheme is especially helpful to get an insight about daily pump operating hours throughout the year. Crop calendar-based irrigation pumping schedule may also be used for this purpose.

Average discharge of a pump can be estimated using the following formula[7]

$$Q = \frac{3950 \times \text{WHP}}{\text{TDH}}, \tag{1}$$

where Q is the flow rate (US gallon/min), WHP the water horsepower and TDH is the total dynamic head (ft).

WHP can be estimated using the following formula

$$\text{WHP} = \text{BHP} \times \text{PE}, \tag{2}$$

where BHP is the break horsepower and PE is the pump efficiency.

TDH can be estimated using the following formula[7,8]

$$\text{TDH} = \text{Static head} + \text{frictional head} + \text{velocity head}, \tag{3}$$

where static head is the average water level (ft), frictional head is the frictional head loss in steady pipe flow and velocity head is the dynamic pressure in flow.

Frictional head can be estimated using the Hazen–Williams equation given below[7,9]

$$F = 0.2083 \times \left(\frac{100}{C}\right)^{1.852} \times \left(\frac{Q_p^{1.852}}{d_h^{4.8655}}\right), \quad (4)$$

where F is the friction head loss (ft) of water per 100 ft of pipe, C the Hazen–Williams roughness constant, Q_p the volume flow (gal/min) and d_h is the inner diameter of the pipe (in).

Here, estimation of F is tricky as it involves the term Q_p which we aim to calculate. The problem may be solved using the empirical formula given below relating rated pump horsepower with pump discharge.

$$Q_p = 13 \times \mathrm{BHP} - 0.75. \quad (5)$$

The empirical formula has been arrived at by plotting several pump discharges ($N = 19$) against the rated pump capacity as observed in the field (Figure 1). This holds true at the pump discharge point with observed pump capacity of 1–5 hp. However, linearity of the graphical relationship allows it to extend further up to 10 hp beyond which pump design changes significantly and the relation may not hold true. The computed equation has been slightly modified to compensate for discharge variation at the higher end. Application of this empirical formula provides an easy method for frictional head computation using the Hazen–Williams equation which is not that sensitive to the value of Q_p and mainly depends on pipe diameter[6]. Table 1 shows the standard roughness constant (C) values for common agricultural tube-well pipe materials used[10,11].

Velocity head being small may be ignored as the flow is considered from the bottom to the top against gravity.

Hence, combining eqs (1) to (4), we get

$$Q = \frac{3950 \times \mathrm{BHP} \times \mathrm{PE}}{\mathrm{WL} + F \times \frac{\mathrm{WL}}{100}}, \quad (6)$$

where WL is the average water level replacing the static head (ft) and F is the frictional head as computed from Hazen–Williams equation.

At present, a new submersible pump has efficiency in the range 65–85% depending on design factors[12,13]. Although a new pump will almost always perform better, its performance drops with time, as the pump begins to wear out. Pump efficiency of 55% is commonly observed in the agricultural sector and also a relatively conservative one.

A case study from Jangipara block, Hoogly district, West Bengal, India, is presented here. The area is completely dependent on agriculture. Historical dataset has been used for data completeness and reliability of the data. Jangipara block covers an area of 163.24 km^2 between

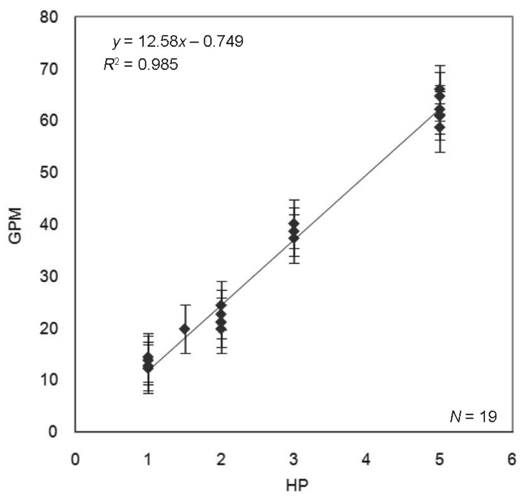

Figure 1. Measured discharge versus rated pump capacity.

Table 1. Standard C values

Pipe material	C value
PVC	130
GI	120
DI	145

Figure 2. Location map of Jangipara block, Hoogly district, West Bengal, India.

Table 2. Crop calendar with pumping schedule in Jangipara block, West Bengal

Month	Crop calendar of Jangipara block										Pumping schedule (h) of Government owned deep tube wells (average of 17 MI schemes)			Average pumping hours
	Til	Jute	Vegetables	Groundnut	Aman	Boro	Potato	Mustard	Wheat	Oilseed	2006–07	2007–08	2008–09	
January							Y	Y	Y		246	175	260	227
February							Y				197	157	311	222
March	Y	Y	Y	Y							267	238	–	253
April	Y	Y	Y	Y							291	201	128	207
May	Y	Y	Y								40	47	66	51
June		Y	Y							Y	31	41	10*	27
July		Y			Y					Y	11	17	26	18
August					Y					Y	52	76	83	70
September					Y					Y	47	44	29	40
October					Y	Y					82	78	99	86
November						Y					35	7*	1*	14
December						Y	Y	Y			126	106	138	123

*Complete data not available.

Table 3. Computation of unit draft

Parameters	Shallow tube well	Deep tube well
Average break horsepower	4.77	16.96
Average pump efficiency (%)	55	55
Average water horsepower	2.62	9.33
Pipe length	11.45 m 37.56 ft	11.45 m 37.56 ft
Flow rate (gal/min)	171.95	598.6
Roughness constant (C)	120	120
Inner hydraulic diameter (d_h; in)	2.5	4
Frictional head (F)	1.32	1.43
Static head (average depth-to-water level)	8.57 m 28.12 ft	8.57 m 28.12 ft
Average total dynamic head	35.60	35.70
Average hourly discharge (Q)	160.5 gal/min 36.5 m^3/h	569.03 gal/min 129.2 m^3/h
Annual pumping hours	1338	1338
Annual unit draft (ha-m)	5.9	20.9

22°40′–22°48′N and 87°58′–88°08′E. The area forms a part of the region covered in the SOI toposheets 79B/1, 79B/2, 79N/15 and 79N/16. Figure 2 shows the location map of the study area. It forms a part of the lower Damodar sub-basin (part of the Ganga basin) represented by gently undulating to flat topography. The area is underlain by thick Quaternary deltaic alluvium, classified as Younger Alluvial Plain. Two major aquifer systems have been identified in the area within a depth range of 200 m. The shallow aquifer system consisting of topsoil layer and underlying fine–medium sand horizon is present to a depth of about 50 m. This horizon is unconfined, but sometimes behaves as semi-confined in the eastern part depending on the thickness of the soil layer. The deeper aquifer system is medium to coarse sand horizon, which is sometimes gravelly and constitutes a confined aquifer. These two aquifer systems are separated by a persistent 18–25 m thick clay layer.

According to the Third MI Census (2000–01), there are 814 shallow tube wells and 20 deep tube wells[14]. Shallow tube wells are commonly fitted with 5 hp pumps, although 3.0 and 7.5 hp pumps are also reported. Reported well diameters vary between 75 and 101 mm, which closely correspond to 3 and 4 inch diameter. Field observations indicate that most of them are of 3 inch diameter. Deep tube wells are commonly fitted with 17.5 hp pumps, though 12.5 and 20 hp pumps are also being used. Reported well diameter in case of deep tube wells is 101.6 mm, which corresponds to 4 inch diameter. Irrigation pumping schedule in Jangipara block has been compiled from the logbooks of 14 Government-owned MI schemes. Table 2 provides the prepared crop calendar with pumping schedule. Measured average depth-to-water level in Jangipara block is 10.45 m in the non-monsoon period. There is not much difference in average depth-to-water level between the two aquifer systems. Table 3

Table 4. Variation in total monthly draft in Jangipara block, West Bengal

Month	Average depth-to-water level (m-bgl)	Monthly pumping hours	Monthly draft by shallow tube wells (ha-m)	Monthly draft by deep tube wells (ha-m)
January	9.70	227	723.62	63.01
February	11.00	222	627.00	54.62
March	12.04	253	654.83	57.05
April	11.08	207	580.56	50.57
May	12.00	51	132.43	11.54
June	9.24	27	90.18	7.85
July	6.23	18	87.40	7.60
August	5.39	70	389.18	33.81
September	5.43	40	220.87	19.19
October	5.64	86	458.36	39.83
November	6.66	14	63.84	5.55
December	8.44	123	447.97	38.99
Total (Annual)	–	1338	4476.24	389.60

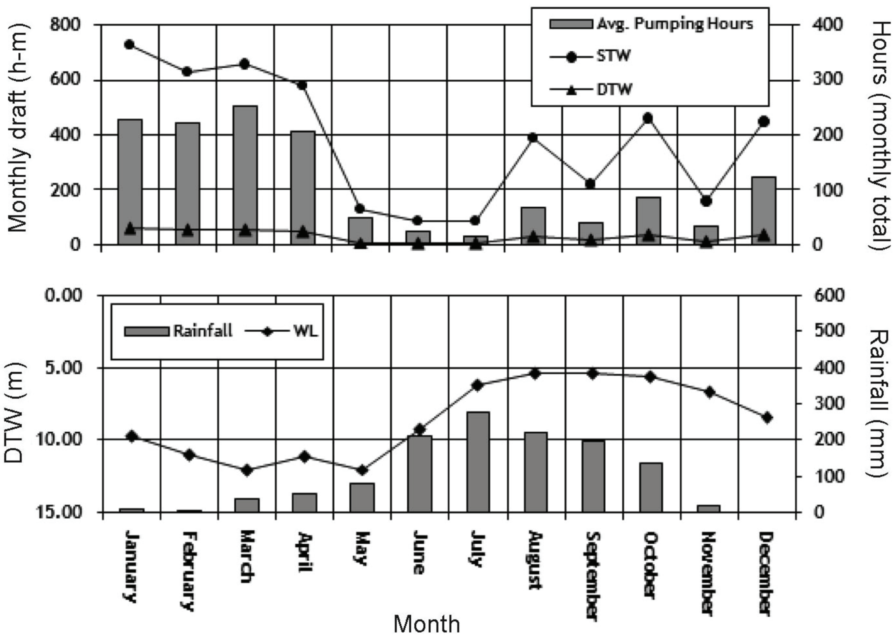

Figure 3. Variation in monthly draft of STW and DTWs against average monthly pumping hours, rainfall and depth-to-water level in Jangipara Block, West Bengal.

summarizes the computed results, based on the Third MI Census data. Computed flow rate (*Q*) is multiplied by average annual pumping hours to arrive at the annual unit draft values. Table 4 shows the month-wise draft in the area based on average monthly depth-to-water level and pumping hours. Figure 3 shows the variation in monthly draft of shallow tube wells and deep tube wells against average monthly pumping hours, rainfall and depth-to-water level in Jangipara block. Observed results have been compared with groundwater resource estimation studies of the area[15]. The study indicates an annual draft of 2507 ha-m through irrigation tube wells, based on groundwater resource estimation norm values utilized for tube-well draft[4]. The present study indicates an annual draft of 4866 ha-m for the same. Hence, the estimate shows about 94% higher groundwater draft compared to the study using standard norms. This is highly likely considering the current practice of agriculture, i.e. high-yielding water-intensive variety of paddy in the area. The increased draft is contributed by higher draft from shallow tube wells which are actually tapping deeper aquifer horizon, and do not comply with standard depth restriction of 30 m for shallow tube wells.

The proposed methodology is a simple and pragmatic approach of unit draft estimation through numerical solution. Detailed MI Census data is the key towards implementation of the method. Though application of Hazen–Williams equation has some limitations[6,9], in most cases in India the method is broadly acceptable, except at high altitudes. The process involves utilization of several well-known empirical formulae for arriving at the solution. However, to retain the original/standardized form of the equations, several conversions of the metric system to FPS system and back are required, which may introduce errors if the user is not careful. Overall, this method for the estimation of unit draft agrees well with field observations.

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