



Design of Dugout Type Farm Pond at the Farm of Chhattisgarh Engineering College, Durg Chhattisgarh

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Authors' contributions

This work was carried out in collaboration among all authors. Author JR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JR and SS managed the analyses of the study. Authors Aman and SK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

To increase food security in a drought-prone area, the water harvesting, capture and storage of rainwater are technologies proven for uses during dry periods. Erosion control and groundwater revive are extra favorable circumstances of water harvesting techniques that contribute to agricultural development and resource conservation. The contour map of the study area is used to select the location for the creation of the farm pond. Clay loam is found in soil texture analysis. For clay loam soil, the study area with a depth of 3.5 m and a side slope of 1.5:1 may be suitable. The available rainfall was computed for 75% probability by using empirical formula is found to 1.41483 ha-m. The tube well draft was calculated to be 0.8640 ha-m. The capacity of the designed farm pond is 0.6639 ha-m. The proposed pond facilitated total supplemental irrigation of 8.5 cm depth to an area of 6.5 ha paddy.

Keywords: Farm pond; supplement irrigation; dugout; rainwater harvesting.

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1. INTRODUCTION

Many small and marginal farmers have found farms fond of an ideal solution to their water struggles. They are small in size and thus fit well within this farmer's landholding size. They can be filled with a small amount of rain. Also, since they are supervised independently, farmers can use uninhabited water without any opposition or conflict. Likewise, farm lakes save women and children from strolling for a significant distance to discover, gather and convey water for home grown use [1]. Farm ponds can also give an extra kind of revenue for families by supporting exercises like fish raising and developing vegetables. Chhattisgarh one of the thirty-five constituents of the country occupies 135194 km² which is 4.14 % of the geographical area of India. The state has 59384 rural pond areas covering 0.751 lakh has and 17.70 irrigation reservoirs covering 0.826 lakh hectare water areas totaling 1.577 lakh hectare water area available for fisheries development at the end of 2013-14.

When rainfall fails to provide adequate moisture for normal plant growth, Supplemental irrigation (SI) is characterized as the addition of small amounts of water to essentially rainfed crops to increase and stabilize yields [2]. Farm Pond is a burrow structure with a clear shape and size having legitimate delta and outlet structures for gathering the surface spillover moving from the homestead territory. It is perhaps the main water reaping structures built at the most minimal bit of the farm area. The stored water should be utilized for irrigation only. Accidentally, a few people utilize the farm ponds as groundwater revive structures which isn't right according to the definition [3].

2. MATERIALS AND METHODS

The study was conducted on the experimental farm of Chhattisgarh Agricultural Engineering College Durg. (C.G.). In the study area, most rainfall occurs due to the south-west monsoon. The onset of monsoon takes place around 10th June and withdraws by the last week of October 2016.

The temperature in the area varies greatly depending on the season, as well as day and night, and the temperature drops dramatically after October. The year's winter season continues until February. The hottest month is May, with a maximum temperature of 45 degrees

Celsius, and the coldest month is December, with a minimum temperature of 11 degrees Celsius. The environment is portrayed by splendid daylight long stretches of over 9 hours. The daytime temperatures during the pinnacle summer season are normally high in the whole region shifting from 39°C to 45°C in the fortnight of May. The relative humidity is low in summer (36%) and reaches up to 86 % during the storm season. The general mugginess stays high all through the stormy season (47% to 86%). The day-by-day mean relative humidity fluctuates from 36 % in April to a limit of 80 % in August. It differs from 33% to 57% throughout the colder time of year month. The normal splendid daylight hours are around 6-7 hours/day during July and August. (IMD, Durg).

2.1 Soil Investigation

For the determination of soil of the study area collected soil sample is investigated by sieve analysis then the hydrometer test is done. The density of the soil is determined by using the density bottle method. Soil samples were collected from different places of the study area, with the help of a soil auger.

2.2 Soil Texture Analysis

Its influences by runoff behavior in any catchment. A particle size distribution curve gives us an idea about the type of soil. Soil classification is done by textural classification which is the triangular classification [4].

2.2.1 Hydrologic and hydraulic design of farm pond

The design's main concern and the challenge are to provide enough water for agricultural operations at a low cost. It entails calculating the design runoff rate that the system must safely manage. The scale, shape, side slopes, and water control systems are all dimensions to consider when designing a pond.

2.3 Probability Analysis

Pond construction is based on probability analysis and the frequency of annual or seasonal rainfall. For probability analysis, it is important to obtain long-term data spanning at least 20 years. Each value for the collected seasonal rainfall should be rated by volume and arranged in descending order [5].

2.3.1 ET requirement of the crop

Secondary data for ET requirements were taken from the work done by Hansa 2010 on "Block-Wise Planning of Crop and Water Resources of Durg District". The total estimated ET requirement of crop paddy is 736.14 mm.

2.3.2 Tube well draft assessment

The average draft of tube wells is computed by the volumetric method. In this method, flow is collected in a known volume for a measured period. The discharge from a tube well is measured with a 20-liter bucket. Make a note of the correct time to fill the 20-liter bucket. To get tube discharge, divide the bucket volume by the time it takes to fill it [6].

2.3.3 Surface runoff

For the calculation of surface water runoff, the minimum data set of daily rainfall data, land use and its distribution, type of soil and infiltration rate of the catchment area, and antecedent moisture condition (AMC) of the watershed based on the previous 5 days' consecutive total rainfall preceding the rainfall considered.

2.4 Curve Number Method

It estimates the direct runoff (depth) or rainfall excess, storm-wise. This method is based on the potential maximum retention(S) of the watershed, which is determined by the wetness of the watershed i.e. the antecedent moisture condition (AMC). For the Black Soil:

$$Q = \frac{(P-0.2S)^2}{P-0.8S}$$

Curve number varies from minimum zero for the most permeable surface or fully saturate to the maximum of 100 for the impervious (Concrete) surface [7].

2.5 Capacity of Pond

At a conservative estimate, a reliable minimum value of seasonal rainfall can be expected to be known as runoff in the case of black soil and 10% of pond capacity in the case of red soil with light to moderate slopes. Rain availability was used at 75% chance probability [8].

2.5.1 Estimation of runoff rate

Design of surface drainage system can be adequately done using the estimated runoff if such estimation is based on the rainfall

parameter $Q = CiA$. Where Q is peak discharge at the outlet of the watershed in m^3/sec . i = uniform rainfall intensity over the whole of the watershed for the desired recurrence interval for the duration of time of concentration of the watershed in m/sec . A is the watershed area in m^2 and C = dimensionless coefficient, it is depending on the land use and soil type [9].

2.5.2 The dimension of farm Pond

Determination of optimum dimension of farm pond, the design based on hydrological condition. It is very important to keep area losses from 10 to 12% in a total catchment area [10].

2.6 Depth

When the pond is constructed with labour, any increase in depths greater than 3.5 to 4.0 meters becomes informal, according to the Center for Water Technology for the Eastern Area. Lifting devices driven by human and animal power become more informal and challenging. As a result, a pond with a depth of 2.5 to 3.5 meters might be suitable in general [11].

2.6.1 The volume of Excavation

The dimensions of different shape of farm ponds can be calculated using the prismoidal formula as given below:

$$V = \frac{A+4B+C}{6} \times D$$

The plan and section views of square shape farm pond are given in Fig. 1 [12]. From the below eqⁿ is the bottom dimensions for square shape pond is derived as given below:

$$X = \sqrt{Z^2D^2 - \left\{ \left(\frac{4}{3} \right) Z^2D^2 - \frac{V}{D} \right\}} - ZD$$

3. RESULTS AND DISCUSSION

3.1 Land Use

The total farm area is about 8.5657 ha for *Kharif* season 6.4457 ha of total farm area is under paddy crop. Generally, the medium duration of a paddy crop of about 120 days particularly varieties like Swarna, IR-36, etc. has been grown. There are only 2.12 ha are under pasture land. One tube well of a discharge capacity of 5 lit/sec is used. There is no fixed cropping pattern for the *Rabi* season.

3.2 Density

The density of the collected sample was computed density bottle method and found to be specific gravity is 2.5.

3.2.1 Texture classification

For the determination of soil texture sieve analysis and hydrometer method is used.

3.3 Hydraulic and Hydrologic Design

3.3.1 Tube well draft

The tube well drafts were measured by using the volumetric method. The average draft of tube well was found to be 5 lit/sec.

3.4 Deficit and Surplus Water

ET requirement of paddy at different standard meteorological week (SMW) or growth stages is shown in Table 2. The deficit and surplus water requirement is given in Table (2) at the different growth stages of paddy.

3.5 Surface Runoff

Surface runoff is calculated using 24-year rainfall data. Maximum rainfall is used in a one-day probability analysis. Table 3 shows the results of the probability analysis. Collecting rainfall data is used to assess antecedent moisture condition (AMC). The AMC of the study area at different probability as shown in Table 4. Curve number of the study area for both pasture and paddy land is given in Table 5.

3.6 Capacity

The capacity of the pond was computed by detecting the tube well draft plus available rainfall

from the ET requirement of the paddy crop. The net ET requirement of the crop was computed by multiplying the area of the paddy crop to the ET depth.

The available rainfall was computed for 75 % probability by using empirical formula is found to 1.41483 ha-m. The tube well draft was computed by the volumetric method value of the tube well draft.

Calculation of tube well draft was calculated to be 0.8640 ha-m. The capacity of the pond has been determined 0.55083 ha-m.

3.6.1 The dimension of farm pond

For the study area, 3.5 m depth may be suitable, and the side slope is 1.5:1 for clay loam soil. The capacity of the farm pond is 0.6609 ha-m. The square shape of the pond is taken and the bottom length and width of the pond is determined and Calculation is shown below:

Area of top of the pond (A) = 48.7 m × 48.7 m

Area of the middle of the pond (B) = 43.45 m × 43.45 m

Area of the bottom of the pond (C) = 38.2 m × 38.2 m

The volume of excavation is determined by the following formula

$$V = \frac{A+4B+C}{6} \times D$$

$$V = 6639.80 \text{ m}^3 \text{ or } (0.6639 \text{ ha-m})$$

Table 1. Particle percentage weight passed by sieve analysis

| Sieve size | wt. retained (gm) | %wt. retained | Cumulative %wt. retained | % passing |
|------------|-------------------|---------------|--------------------------|-----------|
| 4.75 mm | 7 | 1.04 | 1.04 | 98.96 |
| 2.0 mm | 10 | 1.49 | 2.53 | 97.47 |
| 600 μ | 19 | 2.84 | 5.37 | 94.63 |
| 425 μ | 3 | 0.44 | 5.81 | 94.19 |
| 75 μ | 13 | 1.94 | 7.75 | 92.25 |

Chart 1. Data of soil sample and hydrometer

| | |
|-------------------------|-----------------|
| Gravel (4.75 mm) | 1.04% |
| Coarse Sand (22mm) | 1.49% |
| Medium Sand (>425 μ) | 2.84+0.44=3.28% |
| Fine Sand (>75 μ) | 1.94% |
| Silt + Clay | 92.25% |
| Grand total | 100% |

Chart 2. Classification of the soil texture of the study area

| Sand % | Silt % | Clay % | Soil type |
|--------|--------|--------|-----------|
| 28 | 35 | 37 | Clay loam |

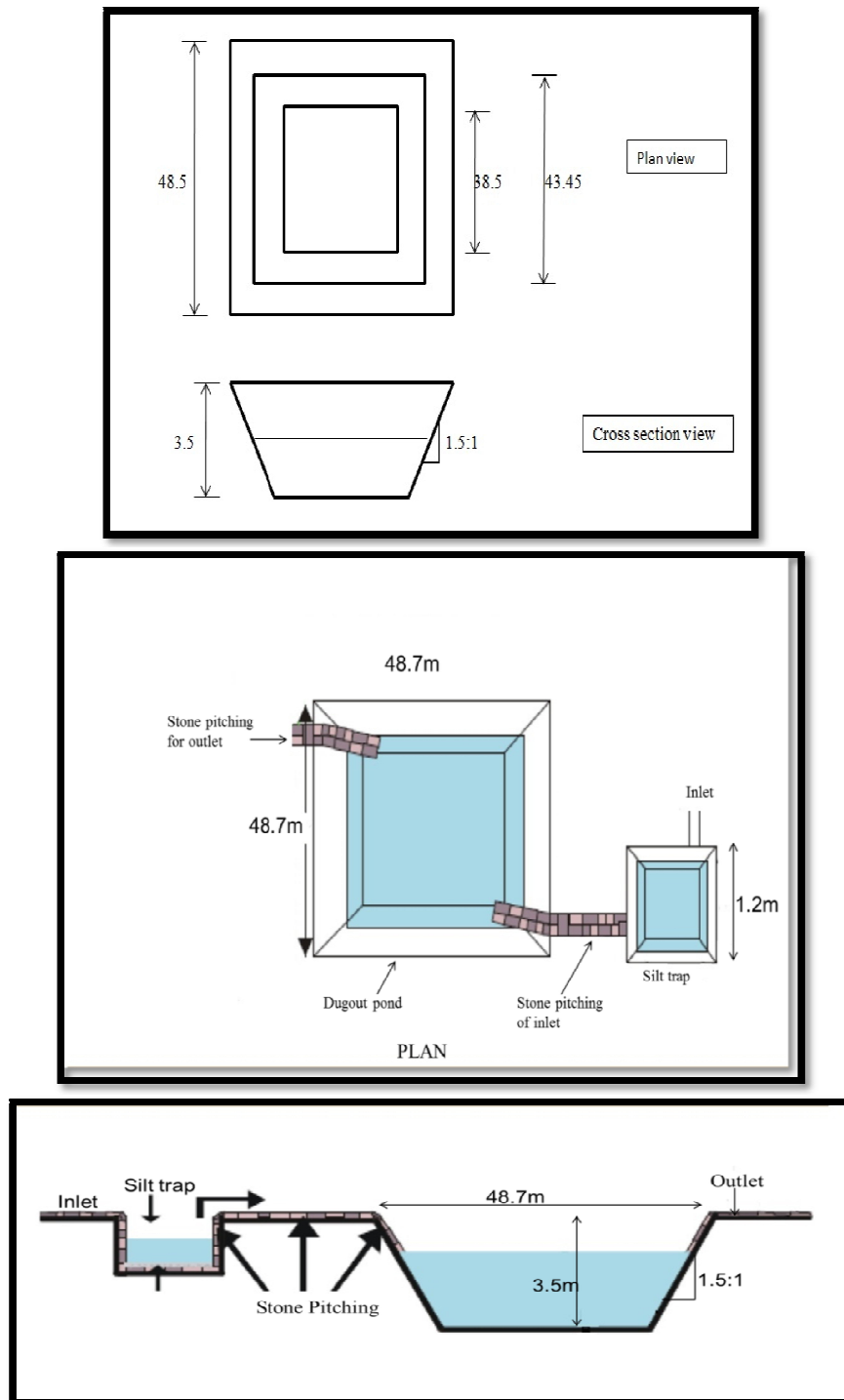


Fig. 1. Plan and cross-section of a farm pond

Table 2. Comparison of available rainfall and ET requirement of the paddy at different stages

| Crop stage | SMW | Total ET(mm) | Available rainfall at 75% Probability | Deficit water (mm) | Surplus water (mm) |
|------------------------------|------------|---------------------|--|---------------------------|---------------------------|
| Nursery | 23-24 | 104.6 | 95 | 9.6 | - |
| Seeding | 25-26 | 68.41 | 63 | 5.41 | - |
| Seeding | 27-28 | 63 | 58 | 5 | - |
| Vegetative (transplanting) | 29-30 | 62.58 | 95 | - | 32.42 |
| Vegetative (tilering) | 31-32 | 59.25 | 72 | - | 12.75 |
| Vegetative (stem elongation) | 33-34 | 60.69 | 75 | - | 14.31 |
| Reproductive (panicle stage) | 35-36 | 54.94 | 51 | 3.94 | - |
| Reproductive (booting) | 37-38 | 67.62 | 27 | 40.62 | - |
| Reproductive (flowering) | 39-40 | 72.27 | 23 | 49.27 | - |
| Maturity (milky/dough) | 41-42 | 66.08 | 12.45 | 53.63 | - |
| Maturity | 43 | 56.7 | 4.7 | 52 | - |
| Total | | 736.14 | 576.15 | 219.47 | 59.48 |

*SMW- standard meteorological week

Table 3. Probability analysis of one-day maximum rainfall

| Year | Rank | rainfall(mm) | probability | Return period |
|-------------|-------------|---------------------|--------------------|----------------------|
| 2009 | 1 | 370 | 4.16 | 24 |
| 2004 | 2 | 337 | 8.33 | 12 |
| 1996 | 3 | 300 | 12.5 | 8 |
| 2002 | 4 | 205 | 16.66 | 6 |
| 1995 | 5 | 197 | 20.83 | 4.8 |
| 2007 | 6 | 168 | 25 | 4 |
| 2010 | 7 | 155 | 29.16 | 3.43 |
| 2003 | 8 | 154 | 33.33 | 3 |
| 2006 | 9 | 144 | 37.5 | 2.67 |
| 2011 | 10 | 142 | 41.67 | 2.4 |
| 2014 | 11 | 133 | 45.83 | 2.18 |
| 2001 | 12 | 129 | 50 | 2 |
| 1997 | 13 | 122 | 54.17 | 1.85 |
| 2012 | 14 | 100 | 58.33 | 1.71 |
| 1998 | 15 | 96 | 62.5 | 1.6 |

| Year | Rank | rainfall(mm) | probability | Return period |
|------|------|--------------|-------------|---------------|
| 1992 | 16 | 90 | 66.67 | 1.5 |
| 2000 | 17 | 88 | 70.83 | 1.41 |
| 1999 | 18 | 86 | 75 | 1.33 |
| 2008 | 19 | 84 | 79.17 | 1.26 |
| 1994 | 20 | 80 | 83.33 | 1.2 |
| 2013 | 21 | 75 | 87.5 | 1.14 |
| 2005 | 22 | 58 | 91.67 | 1.09 |
| 1991 | 23 | 55 | 95.83 | 1.04 |
| 1993 | 24 | 45 | 100 | 1 |

Table 4. AMC condition of the study area at different probability

| Probability (%) | Rainfall (mm) | Date | 5-day antecedent rainfall, mm | AMC Condition |
|-----------------|---------------|------------|-------------------------------|---------------|
| 50 | 129 | 14/06/2001 | 76 | III |
| 67 | 90 | 20/10/1992 | 40 | II |
| 75 | 86 | 09/10/1999 | 70 | III |

**AMC- antecedent moisture condition*

Table 5. CN of the study area at different AMC condition

| Land Use | Area (ha.) | Curve Number | | |
|----------|------------|--------------|--------|---------|
| | | AMC-I | AMC-II | AMC-III |
| Pasture | 2.12 | 53 | 74 | 88 |
| Paddy | 6.45 | 89 | 95 | 96 |

4. CONCLUSION

The topographic survey of the study area has done by using the square grid method of differential height and taken arbitrary benchmarks. The contour map of the study area is used to select the location for the creation of the farm pond. Clay loam is found in soil texture analysis. For clay loam soil, the study area with a depth of 3.5 m and a side slope of 1.5:1 may be suitable. The available rainfall was computed for 75 % probability by using empirical formula is found to 1.41483 ha-m. The tube well draft was calculated to be 0.8640 ha-m. The actual capacity of the pond has been determined 0.55083 ha-m, but consider freeboard the capacity of the designed farm pond is 0.6639 ha-m. The proposed pond facilitated total supplemental irrigation of 8.5 cm depth to an area of 6.5 ha paddy. Suitable dimensions of the inlet, outlet, and silt trap have been designed for the better quality and durability of the structure.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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