

SYSTEM LOSS STUDIES OF VILLAGE TANKS

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ABSTRACT

A considerable percentage of the storage is wasted in village tanks. This loss depends on geometry of the tank and seepage characteristics of the bund and the tank bed. It varies with storage and the rate of evaporation. A systematic study of these parameters may lead to development of a strategy to minimize this loss and optimum utilization of storage. An analysis of the losses indicates that Storage Half Life of a tank can be considered as a comparable index which represents its water storing efficiency.

INTRODUCTION

There are a large number of working and abandoned village tanks in the Dry and Intermediate Zones of Sri Lanka. These are irrigation works from which the issue of water is controlled by members of the community who use it. (Robert Chambers, 1978). Typical dry zone villages are based on small seasonal reservoirs, most of which go dry and are replenished with *Maha* rains (October to December).

The village tank is a small scale water conservation structure which stores water flowing from its own catchment. High degree of uncertainty and poor distribution of rainfall justify the presence of such structures to store upstream run off and to provide supplementary irrigation to the crop as and when needed. The importance of village tanks is further enhanced by the non availability of adequate ground water resources as evidenced by the geo-hydrological features.

Several development schemes have been implemented to improve the village tank based farming system through restoration and rehabilitation of abandoned and partially working village tanks. Instead of renovating each and every abandoned tank, it is essential to plan an overall network of streams and dams for the entire Dry Zone based on hydrological and ecological concepts. Small agriculture based settlements are "mushrooming" with increasing population, most of them not adequately planned.

Development of the village tank in a particular location may be dictated by shape of the valley, presence of an impervious rock basement and the availability of suitable soil for bund construction. To minimize the evaporation loss and reduce the cost of bund construction it is ideal to have the shape with a longer throwback. This can be found in a wide valley with a narrow gorge or in a changing site of the stream bed from flat to steeper gradient, or at the confluence of two streams. (Hudson, 1975).

In irrigation schedules, availability of water in the tanks is important information which needs to be estimated with great care. However, information on the losses of stored water is seriously lacking, except in some isolated cases (Somasiri, 1979).

In this paper an attempt is made to discuss the nature of tank water losses, to introduce a methodology to estimate percent tank water loss of the instant storage and to determine an index which represents the efficiency of a tank on its water bearing characteristics.

PROCESS OF WATER MOVEMENT

As water moves from the catchment towards the crop it creates a hydrologic network. A simple illustration of this system is given in figure 1. It shows that the system efficiency depends on performance of several components such as catchment, reservoir, channel and field. Losses taking place at different components are identified as follows:

1. Catchment Losses — Evaporation, evapotranspiration and percolation.
2. Tank Losses — evaporation, deep percolation, bund base seepage, bund leakage and spill overflow.
3. Channel losses — evaporation, percolation and seepage.
4. Field losses — evaporation, evapotranspiration, percolation and overflow.

Methods have been developed to determine or to estimate catchment loss, conveyance loss and field loss. Information is available for most locations or can be extrapolated with reasonable accuracy.

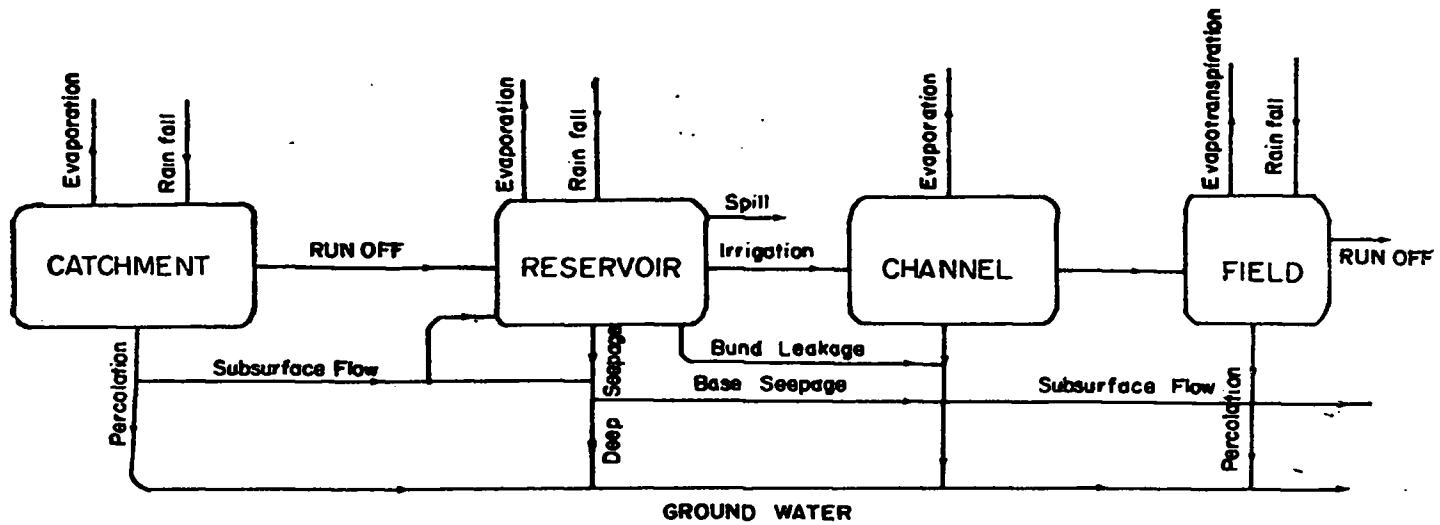


Fig. 1 SCHEMATIC REPRESENTATION OF WATER MOVEMENT

TANK WATER LOSS

Water outflow from the tank is due to evaporation, deep percolation, bund base seepage, bund leakage, irrigation and spill overflow. Irrigation issues are not considered as a loss. Spill overflow is also out of the scope of this paper as it does not affect the storage of the tank.

But an attempt is made to identify the nature of the combined effect due to bund leakage, bund base seepage and percolation losses termed as 'usual loss'. This loss can be determined only during short periods in which apparent inflow and irrigation issues are nil. (Somasiri, 1979). But there may be regeneration from the catchment which is difficult to separate during short dry spells. Hence the term 'Usual Net Loss' is used in this text.

Somasiri (1979) reported that water losses from village tank Walagambahuwa ranged from 5.2 mm to 10 mm/day with an average rate of loss of 6.2 mm/day in *Maha* and 7.5 mm/day in *Yala* Season.

According to the same report there is not much difference between average pan evaporation values in *Maha* (3 mm/day) and in *Yala* (3.5 mm/day) with respect to the average tank loss values.

Roonage (1984) found that the total tank water loss from Walagambahuwa during a dry month is about 12% of the total tank storage.

PROCEDURE

Data analysed in this study are also from the water balance study conducted at Walagambahuwa tank. The tank covers 31 hectares and stores 34.5 ha.m (280 ac.ft.). The full supply level is 3.38 m above the sluice. The catchment area is 114 hectares and the command area of the tank is 13 hectares (Somasiri, 1979).

Water balance data of four years from 1980—1983 were used. Falling rate of the tank water level was taken during periods of about 5 days in which neither irrigation issues nor inflow had taken place. To avoid periods with subsurface flow to the tank the five day durations were selected leaving four days after the rain ceased.

Data sheet was prepared for the analysis adopting the procedure listed below:

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1. Falling rate of the tank water level is calculated for each period as follows: (1.b)

$$\text{Falling rate (cm / week)} = \frac{\text{Water level on 1st day} - \text{Water level on last day}}{\text{No. of days}} \times 7$$

2. Mean Water level is noted against the falling rate.

$$\text{Mean Water level} = \frac{\text{Water level on 1st day} + \text{Water level on last day}}{2}$$

3. The data are arranged in ascending order of the mean water levels.
4. The mean water levels which are very close to each other are grouped together by an average height or a head range to form a set of ranges (1.a).
5. Corresponding surface area (1.c) and storage values (1.d) are entered against head ranges by using Area — Capacity curves of the tank.
6. 'Usual Net Loss' is calculated as follows: (1.e)

$$\text{Water Loss (m}^3\text{/week)} = \frac{\text{Falling rate (cm / week)} \times \text{Surface area (ha)} \times 100}{100}$$

Table 1. Usual Net Loss data for Walagambahuwa Tank (1980 — 1983)

a	b	c	d	e	f	g
Head range in meters	Falling rate cm / wk	Water surface area in ha.	Storage in m ³ / wk. × 1000	Usual Net Loss in m ³ / wk × 1000	% Loss per week	ln (% loss/wk)
0.30—0.45	4.9	1.9	3.7	0.93	25.1	3.22
0.46—0.60	4.6	2.3	6.8	1.05	15.6	2.74
0.61—0.75	4.9	2.7	9.2	1.34	14.5	2.67
0.76—0.90	4.6	3.3	13.5	1.51	11.2	2.41
0.91—1.05	5.5	3.9	18.5	2.13	11.5	2.44
1.06—1.20	4.9	4.9	24.4	2.40	9.9	2.29
1.21—1.35	5.5	6.1	32.5	3.37	10.4	2.34
1.36—1.50	5.8	6.7	42.5	3.86	9.1	2.21
1.51—1.70	6.1	7.8	53.9	4.73	8.8	2.17
1.71—1.85	5.2	9.5	67.1	4.92	7.3	1.99
1.86—2.00	4.3	11.1	81.9	4.72	5.8	1.75
2.01—2.15	4.9	12.4	98.3	6.03	6.1	1.81
2.16—2.30	4.9	13.5	117.6	6.58	5.6	1.72
2.31—2.45	5.2	14.7	139.9	7.62	5.5	1.70
2.46—2.60	3.7	16.4	139.5	6.01	3.7	1.30

RESULTS AND DISCUSSION

Statistical analysis proved that seasons have no effect on falling rate at any head range. Therefore all possible data of four years from 1980—1983 were considered together. This shows that seasonal variation of the evaporation may not be the dominant parameter on tank water loss when related to the tank water level.

An interesting correlation (Fig. 2) found between head range and water loss is given below.

$$\log_e (\% \text{ UNL} / \text{week}) = 3.191 - 0.695 \text{ Head}, r^2 = 0.93^{***} \dots\dots(1)$$

Where UNL = Usual Net Loss

$$\text{and \% UNL} = \frac{\text{UNL}}{\text{Storage}} \times 100$$

Usual Net Loss values were plotted against respective storage values (Fig. 3). There is a definite relationship between loss and the storage. Loss varies with storage in Walagambahuwa tank according to the following equation :

$$\text{UNL} = 1.82 \ln s - 2.63, r^2 = 0.92^{***} \dots\dots (2)$$

Where UNL in 1000 m³ / wk and

S is storage in 1000 m³

Fig. 2 and equation 1 show that percent loss decreases when the head increases. Therefore, one can expect a very high percent loss when tank is having low storage. This is confirmed by Fig. 3. This plot also indicates that the loss reaches its maximum value as tank gains its full capacity level.

Analysis was extended using values computed from equation 2 to determine the effect of reservoir geometry on water loss. (Table 2).

Falling rate was found to be linearly related to the elevation of reservoir water level (Fig. 4). The equation in case of Walagambahuwa tank is as follows:

$$\text{Falling rate (cm / week)} = 8.01 - 1.55, \text{ Head, } r^2 = 0.9^{***} \dots\dots (3)$$

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**Fig 2. Relationship Between Usual Net Loss And the Head.
Walagambahuwa Tank.**

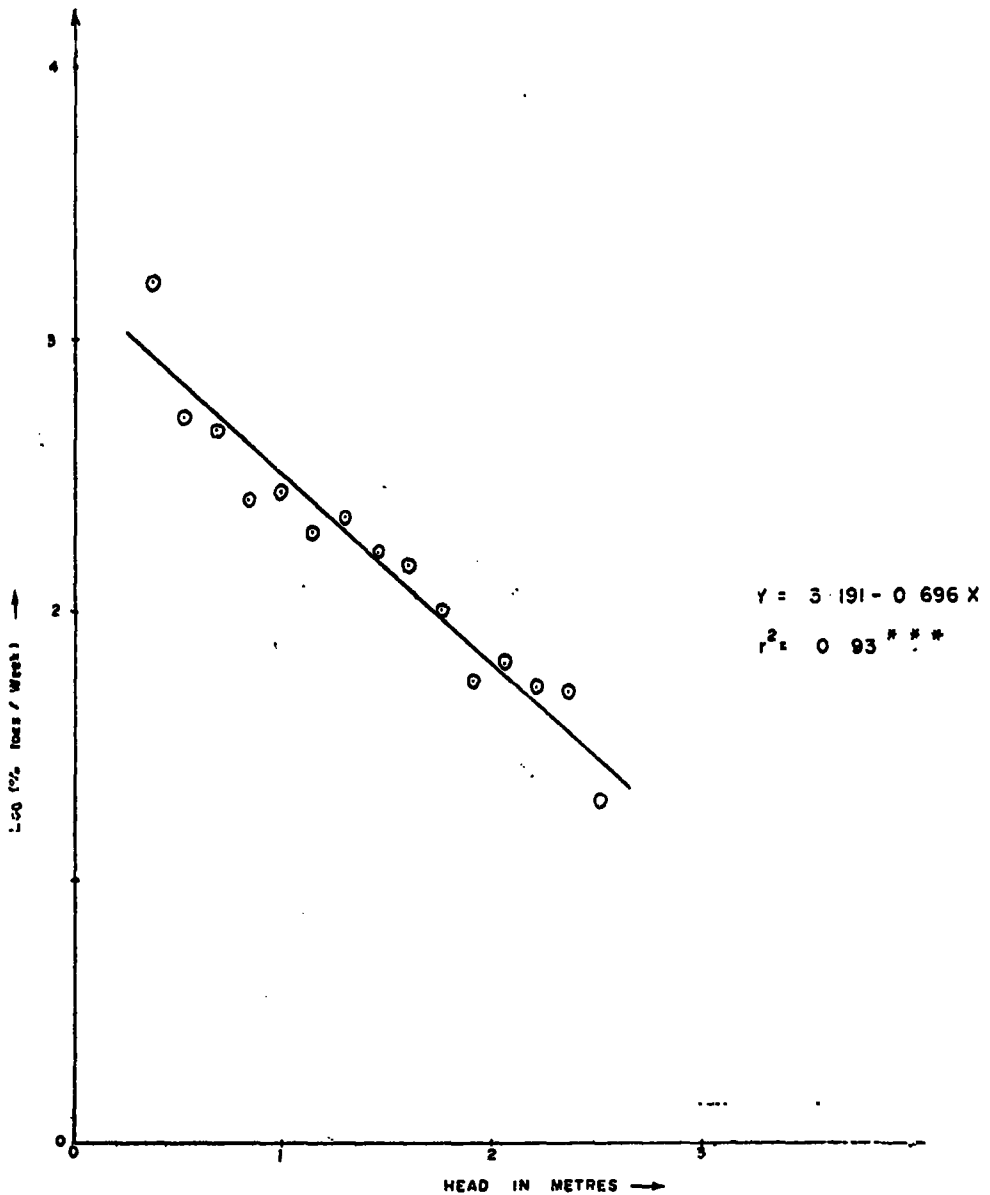
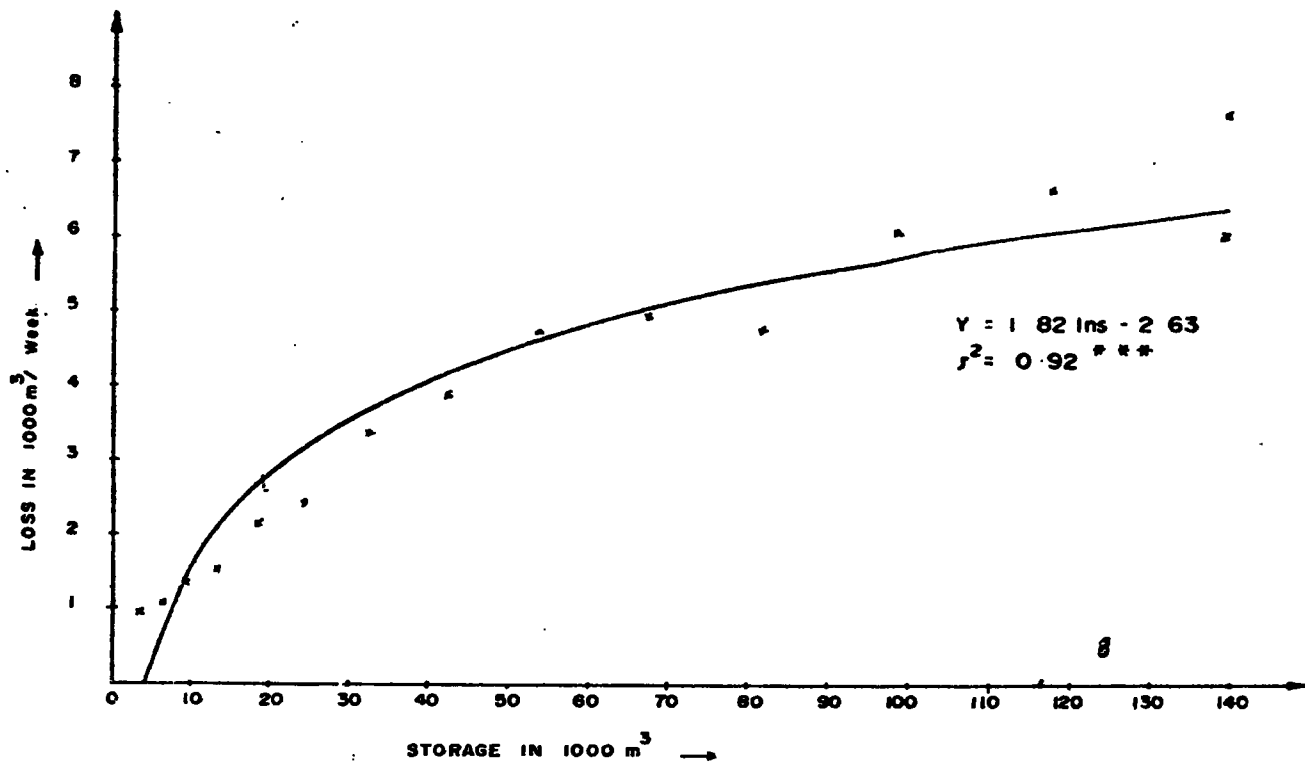


Fig. 3. Variation of the Loss with Storage.
(Walagambahuwa Tank)



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Fig. 4 Falling rate Vs Head.

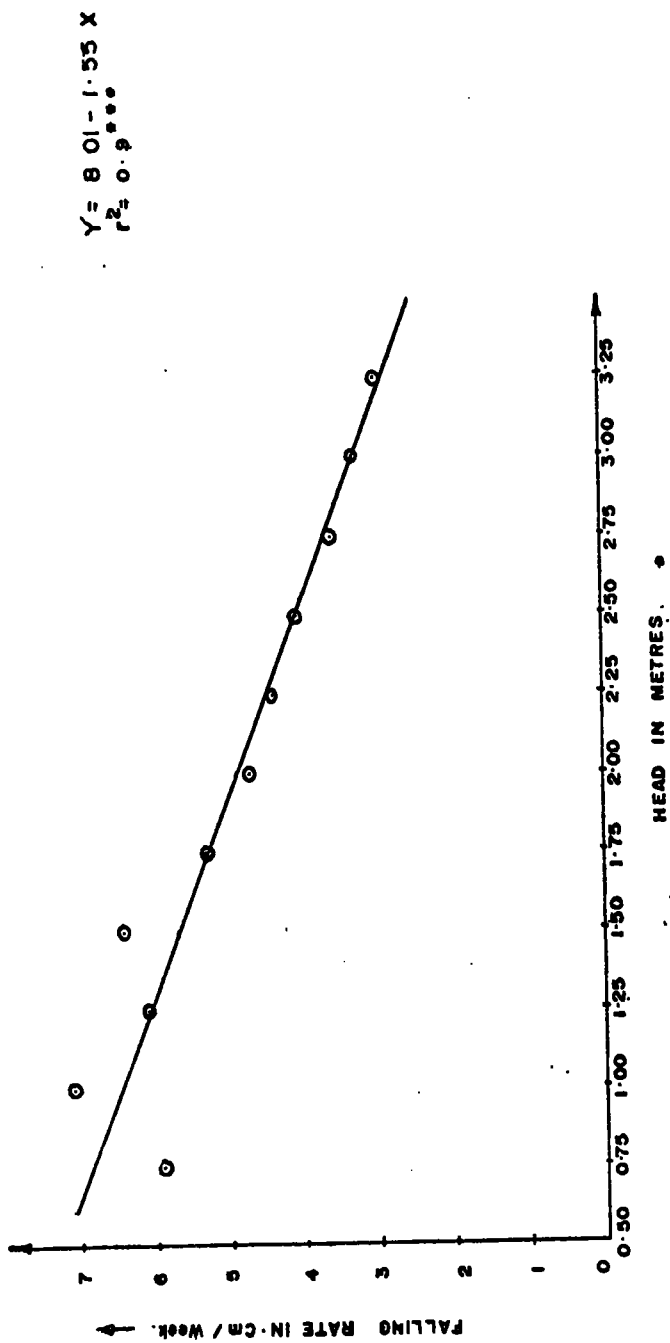


Table 2. Computed Loss and Falling Rate Values Using

$$\text{UNL} = 1.82 \ln S - 2.63$$

where UNL = Usual Net Loss in 1000 m³ / wk.

S = Storage in 1000 m³

<i>Head in meters</i>	<i>Water surface area in ha.</i>	<i>Area / Depth ratio in 10000 m.</i>	<i>Storage in 1000 m³</i>	<i>UNL in 1000 m³ / week</i>	<i>Falling rate cm / wk.</i>
0.75	2.99	3.99	11.08	1.75	5.9
1.00	3.88	3.88	10.09	2.74	7.1
1.25	5.82	4.66	30.17	3.57	6.1
1.50	6.79	4.53	46.18	4.34	6.4
1.75	9.45	5.40	66.86	5.02	5.3
2.00	11.92	5.96	91.12	5.58	4.7
2.25	13.82	6.14	123.14	6.13	4.4
2.50	16.24	6.50	161.93	6.63	4.1
2.75	19.39	7.05	205.03	7.06	3.6
3.00	23.03	7.68	261.06	6.50	3.3
3.25	26.66	8.20	320.16	7.87	3.0

Since only the water depth does not represent the entire geometry of reservoir water body, Area : Depth ratio was considered as the parameter for the falling rate of tank water level. This relationship was also found to be linear (Fig. 5) and the fitted regression line is given by :

$$\text{Falling rate (cm / week)} = 10.15 - 0.9 \frac{\text{Area}}{\text{Depth}} \cdot 10^4 \text{m}, r^2 = 0.95^{***} \dots \dots (4)$$

This concludes that the variation of the falling rate is due to the geometry of the water body. Parameters of the straight line represent the effect of geometric nature of the tank bed and the bund on water loss. However these relationships may not be valid for very low storage status.

Studies were also directed to obtain an index representing the overall water storing efficiency of the tank. Weekly reduction of the storage only because of Usual Net Loss was computed by using Equation 2. Then the pattern of the storage depletion in Walagambahuwa tank was plotted against time (Fig. 6). This shows that the Usual Water Loss of the tank is exponential with time. The equation found for the respective tank is :

$$\ln S = 6.14 - 0.05t, r^2 = 0.95^{***} \dots \dots (5)$$

Where S is storage in 1000 m³ and

t is time in weeks.

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Fig. 5. Falling rate Vs Area-Depth ratio

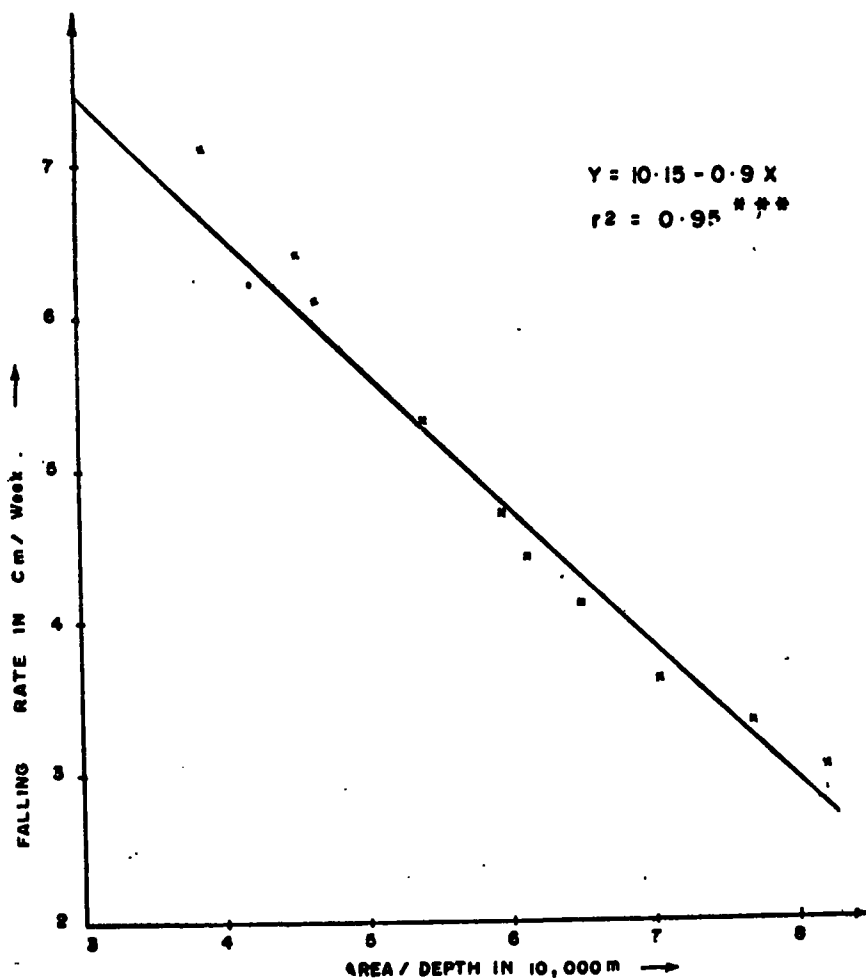
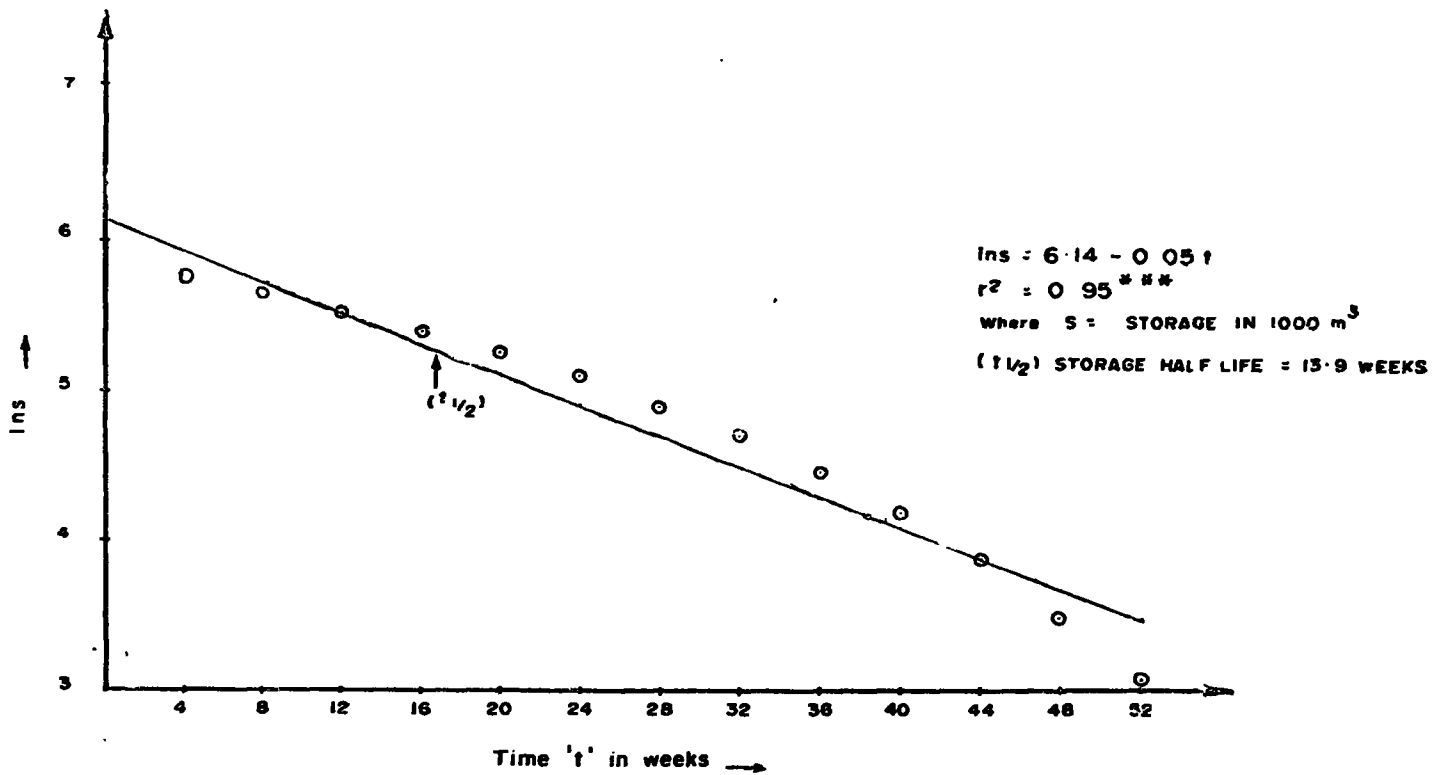


Fig. 6. Exponential Decay Curve of Walagambahuwa Tank



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Comparing this behaviour of reservoirs with the decaying nature of radio active elements, an important index could be introduced, referred to as the Storage Half Life.

Equation 5 can be rearranged and expressed in a general form as :

$$S = S_0 e^{-kt} \dots\dots (6)$$

There S_0 is the storage at $t = 0$ and k is a constant for a reservoir.

Let the storage at time t_1 be S_1 and storage at time t_2 be S_2 .

If S_2 is half of S_1 , $(t_2 - t_1)$ is called Storage Half Life denoted by $t_{\frac{1}{2}}$,

$$\ln S_1 = \ln S_0 - kt_1 \dots\dots (7)$$

$$\ln S_2 = \ln S_0 - kt_2 \dots\dots (8)$$

Subtracting equation (8) from (7),

$$\ln \left(\frac{S_1}{S_2} \right) = k (t_2 - t_1)$$

$$\text{If } \frac{S_1}{S_2} = 2 \text{ and } k = 0.05 \text{ (equation -5)}$$

$$(t_2 - t_1) \text{ or } t_{\frac{1}{2}} = 13.9 \text{ weeks.}$$

Therefore storage Half Life of Walagambahuwa tank is 14 weeks.

Similarly the constant k (to be referred to as Water Loss Constant) also shows the nature of water loss of a given tank. These two parameters can be used for evaluation of tanks on water storing efficiency. Tanks with higher $t_{\frac{1}{2}}$ and lower k values will exhibit better efficiency as water conserving structures.

CONCLUSIONS

1. Usual Net Loss decreases with the increase of tank water level.
2. Water Loss increases with storage up to a maximum value.
3. Falling rate due to Usual Net Loss is linearly decreasing as head increases.
4. Falling rate due to Usual Net Loss is linearly related with Area : Depth ratio. Nature of this relationship represents the effect of tank geometry on water loss.
5. Storage Half Life and Water Loss Constant can be considered as indices of water storing efficiency of village tanks.

Terminology

- Usual Net Loss** — The apparent reduction in the storage of a tank when there is no irrigation issue and no surface runoff and direct rainfall to the tank.
- Decay Curve** — The curve representing the change in storage when there is no other recharge or discharge except Usual Net Loss.
- Falling Rate** — Rate of reduction in tank water level.
- Storage Half Life** — Time taken to reach half the storage of initial level if only Usual Net Loss takes place.
- Water Loss Constant** — A dimensionless constant for a tank showing its water storing efficiency.

ACKNOWLEDGEMENT

The author is indebted to S. Somasiri (Head, Land & Water Use Division) for his initial guidance and instruction in the preparation of this paper and the data supplied by the Division. Criticism and valuable suggestions made by S. D. Khepar, Consultant (ADZAP) G. B. Keerthirathna and H. B. Nayaka Korale (Research Officers) in preparation of this paper are also gratefully acknowledged.

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